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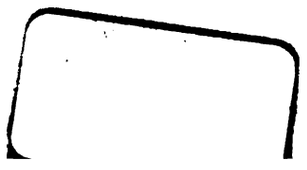

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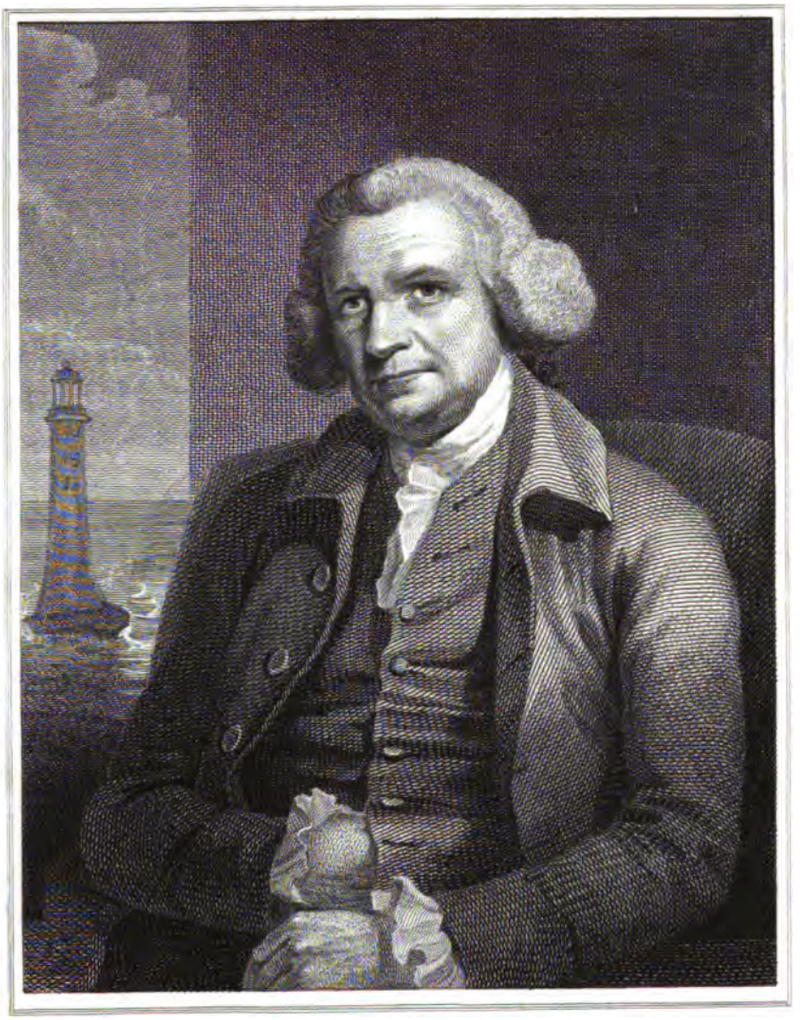

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Civil Engineer, F.R.S.

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JOHN SMEATON, F.R.S.

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IN THE COURSE OF HIS EMPLOYMENT

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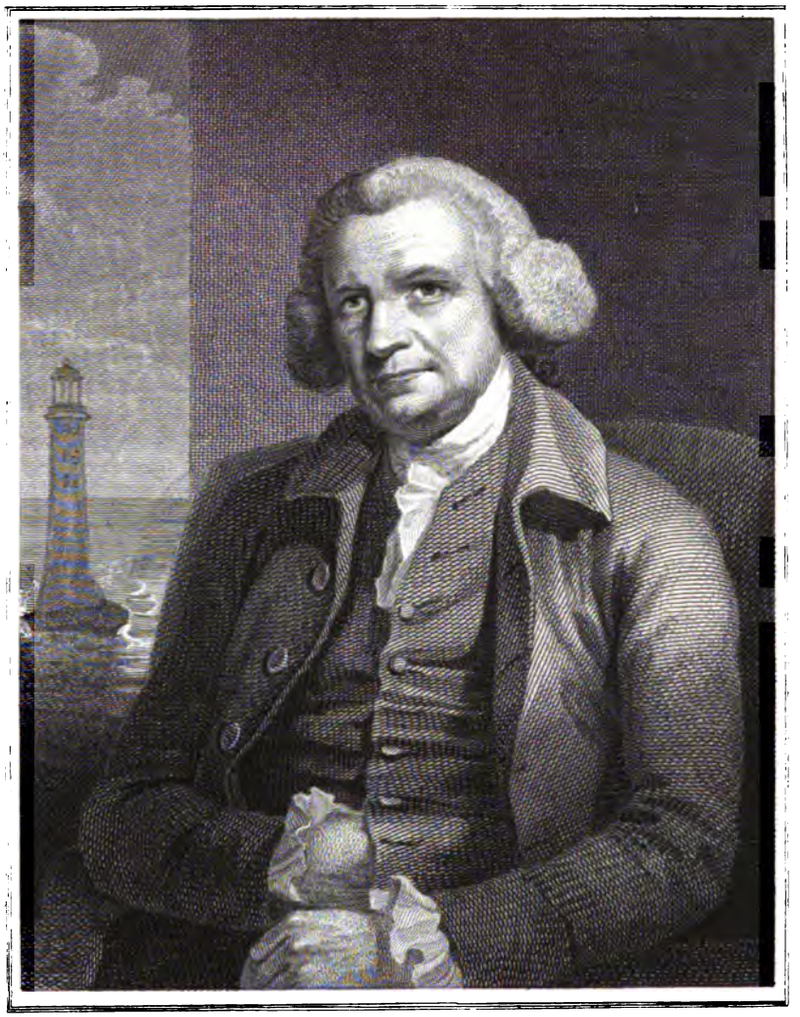

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When we consider the intimate relation between the success of engineering operations and commercial enterprise, we can scarcely attach a too high value to those books which in any way assist in explaining the works that have been executed, the difficulties encountered, and the means by which those difficulties were overcome. The extension of commerce greatly depends on the engineer, for he is chiefly employed in works of national necessity, in facilitating the communication between distant places, and in providing those mechanical arrangements by which the manufactories are carried on: in fact, the wealth of a country greatly depends on the skill and intregity of its engineers. The architect has an altogether different object in view; it is his concern to gratify the taste or caprice, and to provide for the comfort, of individuals. The architect may be said to influence society, in some degree, by the erection of edifices calculated to refine the public taste, in the same manner as an author exercises an influence, more or less active, upon the intellectual and moral feelings of his readers. But those writers are in error who assert that public architectural taste is formed by the professors of the art. We are accustomed to judge of the habits and civilisation of nations at different periods, by their architectural remains, thereby admitting public taste to direct the architect. The engineer, on the other hand, though prompted by the wants of society, is constantly creating others by the improvements he introduces. No sooner does a necessity exist, than he meets it with an appropriate invention, and thus improves the condition of that society whose intellect and energy have given activity to his skill. We might illustrate this remark by reference to the introduction of railways. A great increase of commerce in Britain, arising from the augmentation of capital, speculative activity, and the introduction of machinery into operative works, called for a more rapid and commodious means of intercourse between the manufacturer and the consumer. The want was met by the introduction of railways, which will, ultimately, create an entirely new system of business, be the means of bringing men nearer to each other, and thus, by offering opportunities of more frequent intercourse, destroy prejudices, strengthen the social tie, and increase the happiness of all. It is in this manner that the engineer is instrumental in forming the habits and promoting the welfare of

society; and it is this circumstance gives an exceeding value to the books which explain the principles and operations of his practice.

The propriety of establishing a marked distinction between those two classes of professional men, who are engaged in designing and in directing the execution of builders' work, may be justly doubted. The disunion of science and art has introduced into the profession of architecture a comparative indifference to the principles of construction, or, at least, a too preponderating regard for the rules and ordonnance of style. The same cause has produced among engineers an improper estimate of the value of the experimental sciences, which, although of the greatest importance, as forming the basis of all professional skill, should not be studied to the neglect of that taste necessary to give beauty to their constructions. It is a singular circumstance, that many of the most eminent engineers of this and of other countries, have entered the profession with no other advantages than those derived from a course of private study, and the casual examination of public works. Such individuals have often been attracted by an intense love of the physical sciences, and have possessed but little judgment in the selection of suitable ornaments for the decoration of their works, and no regard for architectural ordonnance. In all their engagements, they appear to have had no other objects than the accomplishment of some mechanical purpose, and the duration of their erections. This indifference to taste has been propagated, and it is only within the last few years the engineer has made the external appearance of his works an object of study. The architects and engineers of this country have, consequently, been accustomed to study an entirely different class of professional works—the former have almost entirely confined their attention to the examination and imitation of the several styles of erecting edifices intended for private comfort or public intercourse: the latter have made the acquisition of the exact and experimental sciences, the object of first importance, and have afterwards been engaged in those works only which required the application of physical principles. But the intellectual character of society is entirely changed: a knowledge of the physical sciences will soon be an indispensable branch of public education, and especially of those individuals who are designed for the practice of architecture. The works which were once only in the possession of the engineer will be studied by his professional colleague: and, although some may, governed by a natural predilection, prefer and follow one branch more than another, the professions will cease to exist as separate studies; and the students of each will esteem the science and the art equally worthy his attention, and necessary to his proficiency.

Considering the science of construction as important to the architect and engineer, we know of no work that has a character so universal as SMEATON's Reports. It is true that Mr. SMEATON's attention was confined to those works which still engage the skill of the engineer, but there is evidence, upon every page, of a quick discerning mind, and a tone of character which cannot fail to instruct the reader and inspire emulation.

In whatever manner we estimate the value of SMEATON's Reports, they recommend themselves to our attention. If we consider them as the records of great

national works, they are interesting, and we find in every page some evidence of the wealth, energy, industry, and genius of our native country. To the man who watches the progressive increase of comfort among the lower classes, as resulting from improvements in the arts, these documents must be valuable: for we have only to compare the condition of many districts spoken of in the following pages, previous to the execution of canals, harbours, or roads, and their state at the present time, to be convinced that the happiness of a country, is essentially increased by all those enterprises which tend to give a facility of intercourse, and to remove the necessity of those labours which, when executed by men, can be hardly less than degrading to the species. If the Reports be only considered as the labour of one man they have an interest of no common order; they are the monuments of a man who was daily engaged in the direction and superintendence of national works, executed in nearly all portions of the kingdom. He who spends a long life immured in his study, free from the care, turmoil, and envy of society, may, at its close, be expected to present some gift to the world in which he has been an apparently unconcerned spectator, if not a useless drone; but that, by the single persevering energy of an individual, so much should have been accomplished as we find Mr. SMEATON to have performed, must stimulate industry and destroy despair. But the Reports are in themselves instrinsically valuable for the engineering information they contain. It is true, that the estimates would no longer be the actual value of the several works, in consequence of the advanced price of both labour and materials, and many of the plans adopted by our author with so much skill, would not be consonant with the discoveries and improvements of our own day; but, as long as an accurate discernment, extensive observation, genius, modesty, and inflexible honesty, are valued, SMEATON's Reports will be read with advantage and followed as models.

Mr. SMEATON's style is not remarkable for its elegance, but it is always clear, and frequently forcible. His writings appear to be a perfect transcript of his mind; a shrewd observation, quick perception, ready invention, and scrupulous honesty, were the characteristics of the man, and they are embodied in his Reports. That we do not over-estimate the intellectual or moral qualities of this great man, will be admitted by all who know the tenor of his life and have had an opportunity of examining his works. To mention any one of his splendid undertakings, or to fix his fame upon any thing less than the whole, would be invidious to his memory, although we might mention many which would singly establish the fame of any living engineer.

It has often happened in this and other countries, that the moral qualifications of professional men have been forgotten. Skill has been considered a sufficient character, and the strict unflinching integrity which may evince itself in adversity as well as in prosperity has been often treated as a matter of no importance. Success has been the test of respectability, and honour, the attendant of fortune. It may be necessary for governments to support themselves by rewarding those whose interest may prolong their authority; but the welfare of a state is best consulted by the employment of those most capable of performing the duties required.

There is no country which ought to excel Great Britain in engineering skill. The opportunities which are offered to the students, the talents of the nation, the wealth and extensive influence of the country, ought to give a perpetuity to that supremacy she has so long been admitted to enjoy. It cannot, however, be denied, that the engineering talent of the country is restricted, and chiefly by placing military men in offices of trust in our colonial possessions. We do not deny that the engineers in the pay of the country and connected with the military are, in many respects, as capable as those in the civil service to perform the duties required in our colonial possessions; but as long as the system of exclusion exists either in a greater or less degree, the legitimate expectations of the man of science will be disappointed, the skill and information of many will be lost to their country, the intelligent and industrious will fail of their reward, and the extension of commerce and its attendant intellectual and civil liberty will be delayed.

The re-publication of SMEATON'S Reports in a form not unworthy the present state of the arts, and at a cost which renders it accessible to all professional men, cannot, we think, fail to be advantageous to the public at large; and it will ever be a satisfaction to the Editor, that he has been in any way connected with an effort to put this valuable Work within the reach of every student.

W. M. HIGGINS, F.G.S.,
ARCHITECT AND ENGINEER;
FORMERLY PROFESSOR OF NATURAL PHILOSOPHY,
GUY'S HOSPITAL.

PREFACE

TO

THE FIRST EDITION.

It is with much satisfaction the Committee of Civil Engineers have, at length, so far accomplished their long wished-for object, as now to present the public, with the first part of the works, of their late worthy and ingenious brother, Mr. John Smeaton; one of the greatest Engineers, that this, or, perhaps, any country, ever produced.

As the members of this Society have interested themselves so greatly in the publication of the present work; and the author of it had so great a share in the first establishment, as well as the subsequent management of the Society, it may not be amiss in this place to employ a few words in giving a short account of it, before any thing is said more particularly of the publication itself.

The origin of the Society of Civil Engineers, took its rise from the following circumstances. Before or about the year 1760, a new era in all the arts and sciences, learned and polite, commenced in this country. Every thing which contributes to the comfort, the beauty, and the prosperity of a country, moved forward in improvement, so rapidly, and so obviously as to mark the period with particular distinction.

The learned societies extended their views, their labours, and their objects of research.—The professors of the polite arts associated together, for the first time; and they now enjoy a protection favourable to improvement, and not less honourable to real merit than to the public, and the throne, which have, with one accord, promoted their prosperity.

Nor have these exertions failed of producing the adequate effects, comparing the present with the past state of things.

Military and naval establishments were made, or enlarged, to promote and extend the true knowledge on which these sciences depend.

The navy of England sails now uncontrolled in every part of the habitable world; and her ships of war defy the combined power of all other maritime nations.

It was about the same period, that manufactures were extended on a new plan, by the enterprise, the capital, and, above all, by the science, of men of deep knowledge and persevering industry engaged in them.

It was perceived, that it would be better for establishments to be set down on new situations, best suited for raw materials, and the labour of patient and retired

industry, than to be plagued with the miserable little politics of corporate towns, and the wages of their extravagant workmen.

This produced a new demand, not thought of till then, in this country,—internal navigation. To make communications from factory to factory, and from warehouses to harbours, as well as to carry raw materials to and from such establishments, became absolutely necessary. Hence arose those wonderful works, not of pompous and useless magnificence, but of real utility, which are at this time carrying on to a degree of extent and magnitude, to which as yet there is no appearance of limitation.

The ancient harbours of this island, it may be said, have ever been neglected, considering the increase of its naval power, and a foreign commerce of which there never has been an example in the history of mankind. The seaports were (I had almost said are) such as nature formed and Providence has bestowed upon us; and they were but little better previous to that period, notwithstanding some jetties and piers of defence, ill placed, had been made and repeatedly altered, without knowledge and judgment, at municipal, not government, expense.

This general situation of things gave rise to a new profession and order of men, called Civil Engineers.

In all the polished nations of Europe, this was, and is, a profession of itself, and by itself.—Academies, or some parts of such institutions, were appropriated to the study of it, and of all the preparatory science and accomplishments necessary to form an able artist, whose profession comprehends the variety of objects on which he is employed; and of which the present work is an example and a proof.

In this country, however, the formation of such artists has been left to chance; and persons leaned towards the public call of employment, in this way, as their natural turn of mind took a bias.—There was no public establishment, except common schools, for the rudimental knowledge necessary to all arts, naval, military, mechanical, and others.

Civil Engineers are a self-created set of men, whose profession owes its origin, not to power or influence, but to the best of all protection, the encouragement of a great and powerful nation;—a nation become so from the industry and steadiness of its manufacturing workmen, and their superior knowledge in practical chemistry, mechanics, natural philosophy, and other useful accomplishments.

When any one who has read the varied particulars of this publication, shuts, and lays it down for contemplation, he will reflect on the natural talents and sagacity requisite in that mind which applies to such a profession; on the patient application necessary to acquire all the subservient learning, previous to the commencement of it; and on the wonderful and varied powers which this work exhibits.

The same period gave rise, also, to an association of some gentlemen, employed as above mentioned. They often met accidentally, prior to that union, in the Houses of Parliament, and in courts of justice, each maintaining the propriety of his own designs, without knowing much of each other. It was, however, proposed by one gentleman to Mr. Smeaton, that such a state of the Profession, then crude and

in its infancy, was improper: and that it would be well, if some sort of occasional meeting, in a friendly way, was to be held; where they might shake hands together, and be personally known to one another;—that thus, the sharp edges of their minds might be rubbed off, as it were, by a closer communication of ideas, nowise naturally hostile; might promote the true end of the public business upon which they should happen to meet in the course of their employment; without jostling one another with rudeness too common in the unworthy part of the advocates of the law, whose interest it might be to push them on perhaps too far in discussing points in contest.

Mr. SMEATON immediately perceived the utility of the idea, and at once embraced it. In March 1771, a small meeting was first established, on Friday evenings, after the labours of the day were over, at the Queen's Head Tavern, Holborn. And, from a few members at first, it soon increased; so that, in the space of twenty years, they amounted to sixty-five and upwards. But of these there were only about fifteen who were real Engineers, employed in public works or private undertakings of great magnitude.

Among these, we find the names of YEOMAN, SMEATON, GRUNDY, MYLNE, NICKALLS, JESSOP, GOLBORNE, WHITWORTH, EDWARDS, JOS. PRIESTLY, Major WATSON, BOULTON, WHITEHURST, RENNIE, WATT, and some others. The other members were either amateurs, or ingenious workmen and artificers, connected with, and employed in, works of engineering.

This association declared itself a Society; and a register was kept of the names and numbers of its members. Conversation, argument, and a social communication of ideas and knowledge, in the particular walks of each member, were, at the same time, the amusement and the business of the meetings.

In this manner, sometimes well attended, and at other times not so, as the members were dispersed all over England, the Society proceeded until May 1792; when it ceased to exist, by mutual consent of the principal members.

Some untoward circumstances, in the behaviour of one gentleman towards Mr. SMEATON, gave rise to the disunion. No one was ever more obliged than that gentleman (who is now deceased) to Mr. SMEATON for promoting him in business, and many essential offices in life. The offence given was done away by an apology, at the desire of the Company, and by the goodnature of Mr. SMEATON; but the remembrance of it had an effect on all present.

Afterwards, it was conceived and intended to renew this Society, in a better and more respectable form. Steps were taken for that purpose, and Mr. SMEATON agreed to be a member. But, alas! before the first meeting could be held, he was no more. He died on the 28th of October, 1792; and their first meeting was in April 1793.

It was conceived it would be a better plan, that the members should dine together, at a late hour, after attendance in Parliament; and pass the evening in that species of conversation, which provokes the communication of knowledge, more readily and rapidly than it can be obtained from private study, or books alone.

The first meeting of this new institution, The Society of Civil Engineers, was held on the 15th of April, 1793, by Mr. JESSOP, Mr. MYLNE, Mr. RENNIE, and Mr. WHITWORTH.

The constitution was agreed on, and afterwards acceded to by all;—That there should be three classes in the Society: The First Class, as ordinary members, to consist of real engineers, actually employed as such, in public or in private service. The Second Class, as honorary members, to consist of men of science and gentlemen of rank and fortune, who had applied their minds to subjects of Civil Engineering, and who might, for talents and knowledge, have been real engineers, if it had not been their good fortune to have it in their power to employ others in this profession; and also of those who are employed in other public service, where such and similar kinds of knowledge is necessary. And, the Third Class, as honorary members, also to consist of various artists, whose professions and employments are necessary and useful to, as well as connected with, civil engineering.

The meetings are held at the Crown and Anchor, in the Strand, every other Friday, during the session of Parliament. And the list of members are of the

FIRST CLASS.—ORDINARY MEMBERS.

WILLIAM JESSOP,
ROBERT WHITWORTH,
JOHN RENNIE, F.R.S. Ed.,
ROBERT MYLNE, F.R.S.,
JAMES WATT, F.R.S. L. and Ed.,
JAMES GOLBORNE,
Sir THOMAS H. PAGE, Knt. F.R.S.,
JOHN DUNCOMBE,
Captain JOSEPH HUDDART, F.R.S.,
HENRY EASTBURNE,
WILLIAM CHAPMAN, M.R.I.A.,
JAMES COCKSHUTT.

SECOND CLASS.—HONORARY MEMBERS.

The Right Hon. Sir JOSEPH BANKS, Bart. P.R.S., Knight of the Order of the Bath, &c.
Sir GEORGE A. SHUCKBURGH EVELYN, Bart. F.R.S.
MATHEW BOLTON, Esq. F.R.S.
General BENTHAM,
JOSEPH PRIESTLY, Esq.
Doctor CHARLES HUTTON, F.R.S.
HENRY OXENDON, Esq.
The Right Hon. the Earl of MORTON, F.R.S.
JOHN LLOYD, Esq. F.R.S.
Right Hon. CHARLES GREVILLE, Esq. F.R.S.

THIRD CLASS.—HONORARY MEMBERS.

WILLIAM FADEN, Geographer,
JESSE RAMSDEN, F.R.S. Instrument-Maker, &c.
JOHN TROUGHTON, Instrument-Maker, &c.
JOHN FOULDS, Mill-Wright, &c.
SAMUEL PHILLIPS, Engine-Maker,
SAMUEL BROOKE, Printer,
JOHN WATTÉ, Land-Surveyor, &c.

It may be mentioned, as a mark of the Society's regard, that a tribute is always paid, after dinner, to the memory of their late worthy brother, JOHN SMEATON. The publication of this work shews that their respect goes further; by contributing a more substantial monument to his fame and character.

The Society having learnt that Sir JOSEPH BANKS had, for a considerable sum, purchased all the manuscripts, designs, drawings of every sort, and all the papers of Mr. SMEATON, from his executors and representatives; with a conditional obligation, that if all or any of these papers should be published, and profit should arise from the publication, such profit or advantage should be made over to the said representatives, for their own use. This was a most liberal engagement on the part of Sir JOSEPH BANKS; and as his avocations, in all the walks of science and natural history, are so extensive, it was proposed to him, and most handsomely acquiesced in, that the Society should undertake to perform the task of publishing the Reports only, with the condition thereto annexed; and that the loss, if any, should be defrayed by themselves, as well as, that the profits, if any, should go to Mr. SMEATON's representatives.

In February 1795, four gentlemen stepped forward for this purpose, who, together with Sir JOSEPH BANKS as one, and at the head of it, under the denomination of a special committee, have agreed to perform this service, such as it is, to the public; and to do it at their own risk, though not to their advantage, as above mentioned.

This Committee consists of

Sir JOSEPH BANKS, Bart. Knight of the Order of the Bath, President of the Royal Society, &c. &c.
Captain JOSEPH HUDDART,
WILLIAM JESSOP, Esq.
ROBERT MYLNE, Esq. and
JOHN RENNIE, Esq.

The Reports, only, were the great object of this Society, and of their Special Committee. These, they thought, would be of the greatest use to the profession, to teach actual and practical knowledge; as well to conceive advice and opinions given, as to convey them, with perspicuity and energy, to others.

Of these Reports, the present volume contains about one half; the remainder being intended for a second volume, if the present shall be approved by public encouragement.*

The manner in which the reports are here arranged, is in chronological order, or the time in which they occurred, for each subject; with this variation, that all the several Reports on the same subject, when there were more than one, made at different times, are here brought together, and placed immediately following each other, as may be observed in several parts, particularly under the head "Carron Furnaces and Water," upon which there were several Reports.

As to Mr. SMEATON's style and language, he had a particular, and in some

* This Second Edition of the entire Reports of SMEATON, it may be assumed, is satisfactory evidence of the public estimation of the Author's labours.

degree a provincial way of expressing himself, and conveying his ideas, both in speaking and writing; a way, which was very exact and impressive, though his diction was far from what may be called classical or elegant. A good workman or artist, of humble pretensions, in that respect, is however always eloquent on the subject of which he is truly master. His language and words, therefore, and even the orthography, have been closely adhered to, without taking the liberty to make any alterations, unless perhaps sometimes in the change of a letter or a word, where a manifest deviation from grammar occurred, such as the author would of himself have altered, had he been the editor.

To this volume is prefixed a Short Account of the Life and Writings of Mr. SMEATON, taken partly from Dr. HUTTON's Dictionary, and partly from additional information supplied by the gentlemen of the Committee.

SOME ACCOUNT

OF

THE LIFE, CHARACTER, AND WORKS

OF

MR. JOHN SMEATON, F.R.S.

Mr. John Smeaton, F.R.S. a very celebrated Civil Engineer, and author of the ensuing Reports, was born the 28th of May, 1724, at Austhorpe, near Leeds, Yorkshire, in a house built by his grandfather, where the family have resided ever since, and where our author died the 28th of October, 1792, in the 68th year of his age.

Mr. Smeaton seems to have been born an Engineer. The originality of his genius and the strength of his understanding appeared at a very early age. His playthings were not those of children, but the tools men work with; and he had always more amusement in observing artificers work, and asking them questions, than in any thing else. Having watched some millwrights at work, he was one day, soon after, seen (to the distress of his family) on the top of his father's barn, fixing up something like a windmill. Another time, attending some men who were fixing a pump at a neighbouring village, and observing them cut off a piece of bored pipe, he contrived to procure it, of which he made a working pump, that actually raised water. These anecdotes refer to circumstances that happened when he was hardly out of petticoats, and probably before he had reached the 6th year of his age. About his 14th or 15th year, he made for himself an engine to turn rose-work, and he made several presents to his friends of boxes, in wood and ivory, turned by him in that way.

His friend and partner in the Deptford water-works, Mr. John Holmes, visited Mr. Smeaton, and spent a month with him at his father's house, in the year 1742, when, consequently, our author was about 18 years of age. Mr. Holmes could not but view young Smeaton's works with astonishment: he forged his own iron and steel, and melted his own metals; he had tools of every sort for working in wood, ivory, and metals; he had made a lathe, by which he had cut a perpetual screw in brass, a thing very little known at that day.

Thus had Mr. Smeaton, by the strength of his genius, and indefatigable industry, acquired, at 18 years of age, an extensive set of tools, and the art of working in

most of the mechanical trades, without the assistance of any master, and which he continued to do a part of every day, when at the place where his tools were; and few men could work better.

Mr. SMEATON's father was an attorney, and was desirous of bringing his son up to the same profession. He was, therefore, sent up to London in 1742, where for some time he attended the courts in Westminster-Hall: but, finding that the profession of the law did not suit the bent of his genius (as his usual expression was), he wrote a strong memorial to his father on the subject, whose good sense, from that moment, left Mr. SMEATON to pursue the bent of his genius in his own way.

Mr. SMEATON after this continued to reside in London; and about the year 1750, he commenced philosophical instrument maker, which he continued for some time, and became acquainted with most of the ingenious men of that time.

This same year he made his first communication to the Royal Society; being an account of Dr. KNIGHT's improvements of the mariner's compass. Continuing his very useful labours, and making experiments, he communicated to that learned body, the two following years, a number of other ingenious improvements, as will be enumerated in the list of his writings, at the end of this account of him.

In 1751, he began a course of experiments to try a machine, of his invention, for measuring a ship's way at sea; and also made two voyages, in company with Dr. KNIGHT, to try it, as well as a compass of his own invention.

In 1753, he was elected a member of the Royal Society; and in 1759, he was honoured with their gold medal, for his paper concerning the natural powers of water and wind to turn mills and other machines depending on a circular motion. This paper, he says, was the result of experiments made on working models in the years 1752 and 1753, but not communicated to the Society till 1759; having, in the interval, found opportunities of putting the result of these experiments into real practice, in a variety of cases, and for various purposes, so as to assure the Society he had found them to answer.

In 1754, his great thirst after experimental knowledge led him to undertake a voyage to Holland and the Low Countries, where he made himself acquainted with most of the curious works of art so frequent in those places.

In December 1755, the Eddystone Lighthouse was burnt down, and the proprietors, being desirous of rebuilding it in the most substantial manner, inquired of the Earl of MACCLESFIELD, then President of the Royal Society, who he thought might be the fittest person to rebuild it; when he immediately recommended our Author. Mr. SMEATON accordingly undertook the work, which he completed with stone in the summer of 1759. Of this work he gives an ample description in a folio volume, with plates, published in 1791: a work which contains, in a great measure, the history of four years of his life; in which the originality of his genius is fully displayed, as well as his activity, industry, and perseverance.

Though Mr. SMEATON completed the building of the Eddystone Lighthouse in 1759, yet it seems he did not soon get into full business as a Civil Engineer; for in 1764, while in Yorkshire, he offered himself a candidate for one of the receivers of

the Derwentwater estate; in which he succeeded, though two other persons, strongly recommended and powerfully supported, were candidates for the employment. In this, he had the faithful and friendly support of Sir FRANCIS GOSLING, Alderman of London, and one of the Commissioners. That estate was forfeited in the year 1715, and the revenues thereof were applied by Parliament towards the fund of Greenwich Hospital. It consists of mines of lead, containing much silver, as well as lands. It required better than common management; and, above all, that knowledge absolutely necessary to bring mines of lead and coal to the most productive effect. This was the object of the commissioners, and it has been amply repaid. Machines of all kinds, and better means on a great plan, were devised for a more easy and ample working these mines, by Mr. SMEATON: while the correct judgment, patient industry, and great abilities and sincerity of Mr. WALTON the younger, of Farnacres near Newcastle, (his partner in the duty of receiver), taking upon himself the management and the accounts, left Mr. SMEATON leisure and opportunity to exert his abilities on these works, as well as to make many improvements in the whole of this estate of Greenwich Hospital.

By the year 1775, he had so much business, as a Civil Engineer, that he was desirous of resigning the appointment for that Hospital; and would have done it then, had not his friends prevailed upon him to continue in the office about two years longer.

Mr. SMEATON having thus got into full business as a Civil Engineer, it would be an endless task to enumerate all the various concerns he was engaged in: a very few of them, however, may be just mentioned in this place. He made the river Calder navigable; a work that required great skill and judgment, owing to the very impetuous floods in that river. He planned, and attended for some time the execution of, the Great, or Forth and Clyde, Canal in Scotland, for conveying the trade of the country either to the Atlantic or German Ocean. When this work had been executed from the Forth towards the Clyde, as far as a point intended for the junction of a collateral canal to Glasgow, the work stopped, and was discontinued a considerable time, by the funds being exhausted. Before that period, Mr. SMEATON had declined accepting his salary, which was five hundred pounds a year, that he might not be prevented from attenting to the multiplicity of other business, and conceiving the resident engineer, Mr. M'KELL, was fully competent to conduct it afterwards. After a lapse of some time, the work was resumed, by public aid, and has been carried on, and lately completed, under the direction of Mr. WHITWORTH, to the great benefit of trade and that country.

On opening the great arch at London Bridge, by throwing two arches into one, and the removal of a large pier, the excavation, around and underneath the sterlings of that pier, was so considerable, as to put the adjoining piers, that arch, and eventually the whole bridge, in great danger of falling. The previous opinions of some were positive, and the apprehensions of all the people on this head were so great, that many persons would not pass over or under it. The surveyors employed were not adequate to such an exigency. Mr. SMEATON was then in Yorkshire, where

he was sent for by express, and from whence he arrived in town with the greatest expedition. He applied himself immediately to examine the bridge, and to sound about the dangerous sterlings, as minutely as he could. The committee of Common Council adopted his advice; which was, to re-purchase the stones of all the city gates, then lately pulled down and lying in Moorfields, and to throw them pell-mell (or *pierre perdu*) into the water, to guard these sterlings, preserve the bottom from further corrosion, raise the floor under the arch, and restore the head of water necessary for the water-works to its original power; and this was a practice he had before and afterwards adopted on other occasions. Nothing shews the apprehensions of the bridge falling, more than the alacrity with which his advice was pursued: the stones were re-purchased that day; horses, carts, and barges, were got ready, and the work instantly begun, though it was Sunday morning. Thus Mr. SMEATON, in all human probability, saved London Bridge from falling, and secured it till more effectual methods could be taken.

In 1771, he became, jointly with his friend, Mr. HOLMES, above mentioned, proprietor of the works for supplying Deptford and Greenwich with water; which, by their united endeavours, they brought to be of general use to those they were made for, and moderately beneficial to themselves.

Astronomy was one of Mr. SMEATON's most favourite studies; and he contrived and made several astronomical instruments for himself and friends. After fitting up an observatory at his house at Austhorpe, he devoted much of his time to it when he was there: even in preference to public business, much of which he declined for the purpose of applying his attentions to private study, particularly to the subject of astronomy.

About the year 1785, Mr. SMEATON's health began to decline; and, in consequence, he then took the resolution to avoid new undertakings in business as much as he could, that he might thereby also have the more leisure to publish some accounts of his inventions and works. Of this plan, however, he got no more executed than the account of the Eddystone Lighthouse, and some preparations for his intended treatise on mills; for he could not resist the solicitations of his friends in various works. Mr. AUBERT, whom he greatly loved and respected, being chosen chairman of Ramsgate Harbour, prevailed upon him to accept the office of Engineer to that harbour, an office established at that time, as he had been occasionally consulted only previous thereto; and to *their joint efforts* the public are chiefly indebted for the improvements that have been made there, within these few years; which fully appears in the Report that Mr. SMEATON gave in to the Board of Trustees in 1791, which has been published in various ways.

The powers of his mind were beginning to fail, in the observation of his intimate friends, and afterwards of all. He is known to have said, on talking of his health, that he found he had suffered more from the application he paid to the scheme, design, and proposition of a canal from Birmingham to Worcester (which was then very much contested in Parliament), than all the business he had ever met with.

Strong exertions were necessary; which, if he had been vigorous as he was wont,

it would have sat easy upon him; but alas! with the deficiency then commenced, it was hard labour indeed, and thereby promoted the ruin fast approaching and much to be lamented.

This lamentable tale is told, for the instruction of those engaged, and so circumstanced, at that period of life, when the powers of the mind are borne down by the complication and vastness of an object submitted to it.

The bill for that work passed by a small majority; but the difficult and contested part of that work has not as yet been attempted. He was not the proposer, but the supporter of that proposition.

It had for many years been the practice of Mr. SMEATON to spend part of the year in town, and the remainder in the country, at his house at Austhorpe. On one of these excursions in the country, while walking in his garden, on the 16th of September, 1792, he was struck with the palsy, which put an end to his useful life the 28th of October following, to the great regret of a numerous set of friends and acquaintance.

The great variety of mills constructed by Mr. SMEATON, so much to the satisfaction and advantage of the owners, will shew the great use he made of his experiments in 1752 and 1753. Indeed he scarcely trusted to theory in any case where he could have an opportunity to investigate it by experiment; and for this purpose he built a steam-engine at Austhorpe, that he might make experiments expressly to ascertain the power of the old, or NEWCOMEN'S, steam-engine; which he improved and brought to a much greater degree of certainty, both in its construction and powers, than it was before.

During many years of his life, Mr. SMEATON was a constant attendant on Parliament, his opinion being continually called for. And here his natural strength of judgment and perspicuity of expression had their full display. It was his constant practice, when applied to, to plan or support any measure, to make himself fully acquainted with it, and be convinced of its merits, before he would be concerned in it. By this caution, joined to the clearness of his description, and the integrity of his heart, he seldom failed having the bill he supported carried into an act of Parliament. No person was heard with more attention, nor had any one ever more confidence placed in his testimony. In the courts of law, he had several compliments paid to him from the Bench, by the late Lord MANSFIELD and others, on account of the new light he threw upon difficult subjects.

As a Civil Engineer, he was perhaps unrivalled, certainly not excelled, by any one, either of the present or former times. His building the Eddystone Lighthouse, were there no other monument of his fame, would establish his character. The Eddystone Rocks have obtained their name from the great variety of contrary sets of the tide or current in their vicinity. They are situated nearly S.S.W. from the middle of Plymouth Sound. Their distance from the port of Plymouth is about fourteen miles. They are almost in the line which joins the Start and the Lizard

Points; and as they lie nearly in the direction of vessels coasting up and down the Channel, they were unavoidably, before the establishment of a lighthouse there, very dangerous, and often fatal to ships. Their situation, with regard to the Bay of Biscay and the Atlantic, is such, that they lie open to the swells of the bay and ocean, from all the south-western points of the compass; so that all the heavy seas, from the south-west quarter, come uncontrolled upon the Eddystone Rocks, and break upon them with the utmost fury. Sometimes, when the sea is to all appearance smooth and even, and its surface unruffled by the slightest breeze, the ground swell meeting the slope of the rocks, the sea beats upon them in a frightful manner, so as not only to obstruct any work being done on the rock, or even landing upon it, when, figuratively speaking, you might go to sea in a walnut shell. That circumstances, fraught with danger surrounding it, should lead mariners to wish for a lighthouse, is not wonderful; but the danger attending the erection leads us to wonder, that any one could be found hardy enough, to undertake it. Such a man was first found in the person of Mr. H. Winstanley, who, in the year 1696, was furnished by the Trinity House with the necessary powers. In 1700, it was finished; but in the great storm of November 1703, it was destroyed, and the projector perished in the ruins. In 1709, another, upon a different construction, was erected, by a Mr. Rudyerd, which, in 1755, was unfortunately consumed by fire. The next building was under the direction of Mr. Smeaton, who, having considered the errors of the former constructions, has judiciously guarded against them, and erected a building, the demolition of which seems little to be dreaded, unless the rock on which it is erected should perish with it.

Of his works, in constructing bridges, harbours, mills, engines, &c., &c., it were endless to speak.

Of his inventions and improvements of philosophical instruments, as of the air-pump, the pyrometer, hygrometer, &c., &c., some idea may be formed from the list of his writings inserted below.

In his person, Mr. Smeaton was of a middle stature, but broad and strong made, and possessed of an excellent constitution. He had great simplicity and plainness in his manners: he had a warmth of expression that might appear, to those who did not know him well, to border on harshness; but, such as were more closely acquainted with him, knew it arose from the intense application of his mind, which was always in the pursuit of truth, or engaged in the investigation of difficult subjects. He would sometimes break out hastily, when any thing was said that was contrary to his ideas of the subject; and he would not give up any thing he argued for, till his mind was convinced, by the deducements of facts, before unknown to him, and by sound reasoning. In all the social duties of life, Mr. Smeaton was exemplary; he was a most affectionate husband, a good father, a warm, zealous, and sincere friend, always ready to assist those he respected, and often before it was pointed out to him in what way he could serve them. He was a lover and an encourager of merit wherever he found it; and many persons now living are in a great measure

indebted for their present situation to his assistance and advice. As a companion, he was always entertaining and instructive, and none could spend their time in his company without improvement.

As to the list of his writings; besides the large work above mentioned, being the History of the Eddystone Lighthouse, and numbers of Reports and Memorials, many of which were printed, his communications to the Royal Society, and inserted in their Transactions, are as follow:

1. An Account of Dr. KNIGHT's Improvements of the Mariner's Compass. An. 1750, p. 513.

2. Some Improvements in the Air-Pump. An. 1752, p. 413.

3. An Engine for raising Water by Fire; being an Improvement on SAVARY's Construction, to render it capable of working itself; invented by M. DE MOURA, of Portugal. Ib. p. 436.

4. Description of a new Tackle, or Combination of Pulleys. Ib. p. 494.

5. Experiments on a Machine for measuring the Way of a Ship at Sea. An. 1754, p. 532.

6. Description of a new Pyrometer. Ib. p. 598.

7. Effects of Lightning on the Steeple and Church of Lostwithiel in Cornwall. An. 1757, p. 198.

8. Remarks on the different Temperature of the Air at Eddystone Lighthouse and at Plymouth. An. 1758, p. 488.

9. Experimental Inquiry concerning the natural Powers of Water and Wind to turn Mills, and other Machines depending on a circular Motion. An. 1759, p. 100.

10. On the menstrual Parallax arising from the mutual Gravitation of the Earth and Moon, its Influence on the Observation of the Sun and Planets, with a Method of observing it. An. 1768, p. 156.

11. Description of a new Method of observing the Heavenly Bodies out of the Meridian. An. 1768, p. 170.

12. Observations on a Solar Eclipse. An. 1769, p. 286.

13. Description of a new Hygrometer. An. 1771, p. 198.

14. An Experimental Examination of the Quantity and Proportion of Mechanical Power necessary to be employed in giving different degrees of Velocity to heavy Bodies from a state of Rest. An. 1776, p. 450.

THE COMMITTEE OF CIVIL ENGINEERS.

Fellfoot, near Kendal, 30th October, 1797.

Gentlemen,

The advertisement relative to the publication of Mr. Smeaton's Works, recalls to my mind a request made from you, through Mr. Brooke, "that his daughters would assist in furnishing any anecdotes illustrative of his life and character." And this recollection calls upon me to apologise for the apparent neglect, as well as to account why an office so pleasant could be delayed for a moment. The fact is, gentlemen, that, however immediate the impulse was to set about it, I soon found, in so doing, the task at once difficult and delicate.

The public ear, I am afraid, is satiated and fastidious; and the plain anecdotes of a plain man like him, though interesting to individuals, could awaken little public curiosity, or perhaps give still less satisfaction when awakened. And, extraordinary as it may seem, his family probably less than others are in possession of anecdotes concerning him; for, though communicative on all subjects, and stored with ample and liberal observations on others, of himself he never spoke: in nothing does he seem to have stood more single, than in being devoid of that egotism which, more or less, affects the world. It required some address, even in his family, to draw him into conversation directly relative to himself, his pursuits, or his success: self-opinion, self-interest, and self-indulgence, seemed alike tempered in him by a modesty inseparable from merit, a moderation in pecuniary ambition, a habit of intense application, and a temperance strict beyond the common standard. And it is owing, perhaps, to this regulation that, through a course of incessant fatigue and incredible exertion, from six years old to sixty, the multiplicity of business and pressure of cares never had power to deaden his affections or injure his temper.

I say "six years old to sixty," because, while in petticoats, he was continually dividing circles and squares; all his playthings were models of machines, which destroyed the fish in the ponds by raising water out of one into another. At school, his exercises in the law, to him not an agreeable destination, his dry though useful attainments, occupied him through the day; but mechanics, and his favourite studies, engrossed the chief of every night, so that his mind appears to have endured an incessant exertion through that period.

It was his maxim, "that the abilities of the individual were a debt due to the common stock of public happiness or accommodation." This appears to have governed his actions through life; for the claim of sociey (thus become sacred) his time was devoted to the cultivation of talents, by which he might benefit mankind, and thenceafter to the unwearied application of them.

Indefatigable in the pursuits they led to, the public are in possession of all which Nature intrusted to him, or the measure of life allowed.

His friends know well how to appreciate the honest man, who valued them. And what he was in his family, every member of it could speak, if called upon, with equal gratitude, pride, and pleasure.

The arrangement of his time was governed by a method as invariable as inviolable; for professional studies were never broken in upon by any one; and these (with the exception of stated astronomical observations) wholly engrossed the forenoon. His meals were temperate, and for many years restricted, on account of health, to rigid abstinence, from which he derived great benefit.

His afternoons were regularly occupied by practical experiments, or some other branch of mechanics. And not more entirely was his mind devoted to his profession in one division of his time, than abstracted from it in another. Himself devoted to his family with an affection so lively, a manner at once so cheerful and serene, that it is impossible to say whether the charm of conversation, the simplicity of instructions, or the gentleness with which they were conveyed, most endeared his home; a home in which, from infancy, we cannot recollect to have seen a trace of dissatisfaction or a word of asperity to any one. Yet, with all this, he was absolute; and it is for casuistry in education or rule to explain his authority: it was an authority as impossible to dispute as to define.

The command of his feelings, and submission of a temper, naturally warm, to reason and benevolence, were strongly illustrated by a circumstance (in my recollection) peculiarly trying to him. It arose from the conduct of a man formerly employed as a clerk, in whom having the highest confidence and esteem, he procured him a similar, though more lucrative situation in a public office; where he served with a fidelity which, in time, promoted him to a station of high trust and responsibility (my father being bound, jointly with another gentleman, for his conduct in a considerable sum). It were needless to say by what degrees in error this man fell: it suffices, that at last he forged a false statement, to meet the deficiency; that he was detected, and given up to justice. The same post brought news of the melancholy transaction, of the man's compunctions and danger, of the claim of the bond forfeited, and of the refusal of the other person to pay the moiety. Being present when he read his letters, which arrived at a period of Mrs. SMEATON's declining health, so entirely did the command of himself second his anxious attention to her, that no emotion was visible on their perusal; nor, till all was put into the best train possible, did a word or look betray the exquisite distress it occasioned him. In the interim, all which could soothe the remorse of a prisoner, every means which could save (which did, at least from public execution), were exerted for him, with a characteristic benevolence, "active and unobtrusive."

The disinterested moderation of his pecuniary ambition every transaction in private life evinced. His public ones bore the same stamp: and, after his health had withdrawn him from the labours of his profession, many instances may be brought forward by those whose concerns induced them to press importunately for a resumption of it: and, when some of them seemed disposed to enforce their entreaties by further prospects of lucrative recompense, his reply was strongly characteristic of his simple

manners and moderation. He introduced the old woman who took care of his chambers in Gray's Inn, and, shewing her, asserted "that her attendance sufficed for all his wants." The inference was indisputable, "for money could not tempt that man to forego his ease, leisure, or independence, whose requisites of accommodation were compressed within such limits."

Before this the Princess DE ASKOFF made an apt comment upon this trait of his character: when, after vainly using every persuasion to induce him to accept a *carte blanche* from the Empress of RUSSIA (as a recompense for directing the vast projects in that kingdom), she observed, "Sir, you are a great man, and I honour you; you may have an equal in abilities, perhaps, but in character you stand single. The English minister, Sir ROBERT WALPOLE, was mistaken, and my sovereign has the misfortune to find *one man* who has *not* his price."

Early in life he attracted the notice of the late Duke and Duchess of QUEENSBERRY, from a strong resemblance to their favourite GAY, the poet. The commencement of this acquaintance was singular, but the continuance of their esteem and partiality lasted through life. Their first meeting was at Ranelagh, where walking with Mrs. SMEATON, he observed an elderly lady and gentleman fix an evident and marked attention on him. After some turns they at last stopped him, and the duchess (of eccentric memory) said, "Sir, I don't know who you are or what you are, but so strongly do you resemble my poor dear GAY, we *must* be acquainted: you shall go home and sup with us; and, if the minds of the two men accord, as do the countenance, you will find two cheerful old folks, who can love you well, and I think (or you are a hypocrite) you can as well deserve it." The invitation was accepted; and, as long as the duke and duchess lived, the friendship was as cordial as uninterrupted; indeed, their society had so much of the play which genuine wit and goodness know how to combine, it proved to be among the most agreeable relaxations of his life. A sort of amicable and pleasant hostility was renewed whenever they met, of talent and good-humour; in the course of which he effected the abolition of that inconsiderate indiscriminate play, amongst people of superior rank or fortune, which compels every one to join, and at their own stake too. My father detested cards; and, his attention never following the game, played like a boy. The game was Pope Joan; the general run of it was high; and the stake in "Pope" had accidentally accumulated to a sum more than serious. It was my father's turn, by the deal, to double it, when, regardless of his cards, he busily made minutes on a scrap of paper, and put it on the board. The duchess eagerly asked him what it was? and he as coolly replied, "Your grace will recollect the field in which my house stands may be about 5 acres, 3 roods, and 7 perches, which, at thirty years purchase, will be just my stake, and, if your grace will make a duke of me, I presume the winner will not dislike my mortgage." The joke and the lesson had alike their weight: they never after played but for the merest trifle.

The manly simplicity of deportment to his superiors, however, was alike free from pretension and servility; and an invariable consideration and kindness to his inferiors produced a singular sentiment of veneration in those who served him.

He always apprehended the stroke which terminated his life, as it was hereditary in his family: he dreaded it only as it gave the melancholy possibility of out-living his faculties, or the power of doing good; to use his own words, "lingering over the dregs, after the spirit had evaporated."

When this really did happen, the composure with which he met it; his anxious endeavour to soften any alarm to his family; his resignation to the event; and his dignified thankfulness on finding, at last, his intellect was spared,—were every way worthy of himself. Still his invariable wish was "to be released."

In the interim (six weeks) all faculties, and every affection, were as clear and animated as at any period of his life. His memory was tenacious, and his ingenuity as active to relieve the inconveniences of his then situation, as such situation gave what *he* termed trouble to those about him.

He expressed a particular desire and pleasure in seeing the usual occupations resumed; and reading, drawing, music, and conversation excited the same interest, the same cheerful and judicious observations, as ever.

He would sometimes complain of his own slowness (as he called it) of apprehension, and then would excuse it with a smile, saying, "It could not be otherwise; the shadow must lengthen as the sun went down!" There was no slowness, in fact, to lament; for he was as ready at calculations, and as perspicuous in explanation, as at any former period. Some phenomena respecting the moon were asked him one evening, when it accidentally shone bright, full into his room. When he had spoke fully on them, his eyes remained fixed upon it with a most animated attention, to us impressive; then, turning them on us with benignity, observed, "How often have I looked up to it with inquiry and wonder! To the period when I shall have the vast and privileged views of an hereafter, and all will be comprehension and pleasure!"

Shortly after, the end he had through life desired was granted; the body gradually sunk, but the mind shone to the last; and, in the way good men aspire to, he closed a life, active as useful, amiable as revered.

MARY DIXON.

REPORTS

OF

JOHN SMEATON, F. R. S., &c.

QUESTIONS

Proposed by the Magistrates and Town-Council of Dumfries, to the Consideration of Mr. SMEATON. October, 1760.

WHAT is the easiest and most effectual method for preserving the town's grounds of Kingholme from the future encroachments of the river?

2d. How can the navigation of the river Nith be most easily improved from Kingholme to Kelton, and the channel rendered less precarious than it is at present?

3d. It is desired that Mr. SMEATON may visit the works carried on in the under part of the river, opposite to the Merse grounds of Netherwood, Cargin, and Laghall; and, upon considering the course of the river, and the situation and extent of these works, to give his opinion how far the navigation of the river will be bettered or injured by such works; and what amendments or alteration of them are necessary for preserving the navigation entire? And in case such works are attempted to be made by other heritors, what orders ought the Magistrates and Town-Council to give thereanent, as being guardians of the public navigation of this river; and how many feet or fathom broad ought the channel to be kept free at those places?

In case it shall be thought proper or necessary that any of the works already erected ought to be destroyed, whether should the stakes be pulled up or knocked down, equal to, or below, the surface of the ground where they now are; and what ought to be done with such parts of the works as are of stone?

EBEN. HEPBURN.
JOHN DICKSON.
WM. CLARK.

ANSWERS

To the Questions proposed by the Magistrates and Town-Council of Dumfries, for the Consideration of J. SMEATON.

HAVING carefully examined the course of the river Nith and the banks thereof, from Dumfries to Kirkonnell on the west side, and from Kelton to Dumfries on the east, both upon the flood and ebb of a spring tide, I am of opinion as follows:—

Answer to Question 1.—Where the banks, by the undermining of the water, tumble down, I would advise them to be sloped as low down as where the water begins to act, and to defend the foot of the slope by rows of stakes, single or double,

according to the violence of the water's action, placed in a direction parallel to the bank, with binders to confine down a lay of fascines pointing towards the water. The slope of the bank must not be greater than to incline five feet backward for every yard of perpendicular height; the surface of this slope to be sodded, sown with hay seeds, or otherwise grassed over as far as the grass will grow, and the remainder covered with gravel, laid partly upon the fascines. The directions of the rows of stakes ought to be suited to the direction of the water, attempting as much as possible a right line or fair curve, avoiding as much as possible all sudden turns and irregularities.

Answer to Question 2.—The channel of the river Nith has so many sudden turns and irregularities, that the tide spends itself among the sinuosities of the river, and in filling up wide spaces above, after having passed through narrower below, and is thereby prevented from mounting to so great a perpendicular height as it would otherwise attain, in the upper parts of the river near Dumfries, in case the course was more straight, and had a more regular contraction; and this disadvantage is still the greater, as the space of time occupied by the tide of flood is so short, that it begins to ebb below, before the loops of the river, in the superior part, have time to fill to the level that the surface had been at in the lower, at high water. The navigation, therefore, seems incapable of any great improvements at any moderate expense, otherwise than by cutting a navigable canal, with proper locks and other works upon it, which can be done for much less than it would cost to make the river itself tolerably regular. But the way to prevent it from growing worse than it now is, must be by hindering it from becoming still more crooked, and growing still more wide above than below, giving as free a passage as possible to the tide of flood, especially in the most contracted places. Whatever contributes to this end tends to preserve it; whatever has a contrary effect must be a detriment to it.

Answer to Question 3.—In visiting those grounds and works, I observed as follows. That Cargin Merse being situated on the concave side, or in the very bottom of a considerable loop of the river, the direction which the current receives from the superior grounds, on tide of ebb, and from the inferior on tide of flood, both strongly tend to carry away the land of Cargin Merse, and thereby to render the loop still deeper: I am therefore of opinion, that the jetties and works there constructed, in as much as they contribute to prevent this loop from growing deeper, that is, the river from growing more crooked, they thereby contribute to the benefit of the navigation. But I am of opinion, that those jetties have been advanced too far into the river, whereby the course of the water has, in that part, been too much contracted; and also that, by being placed across the direction of the stream, they have contributed to hinder the free passage of the tide of flood, which would of consequence not fill the upper part of the river to so great a perpendicular height, as has been already mentioned. However, as those jetties have in some measure answered one good purpose, viz. that of preventing the river from falling into a deeper loop in that place, and as it might be of dangerous consequence to disturb the body of sleech there gathered, by totally rooting up those jetties, I am of opinion that such of the jetties as run across, or intercept the current, should be levelled with the present surface of the sleech, which may be done either by driving down or sawing off the stakes. As to the jetties that have been formed on the Netherwood side, as they do not seem to have contributed to save the land, or to have answered any one purpose whatsoever, nor do they seem to produce any other effect than that of contracting the river in this, the otherwise narrowest, part, and that of intercepting the current on tide of flood; both which, considering the large wide bay just above,

and the various meanderings still higher, together with the smallness of the time that the tide of flood acts at this place, I am of opinion, that those jetties are very prejudicial to the navigation, and therefore think that all of them, whether of wood or stone, should be pulled up, or otherwise levelled with the present bed of the river on which they stand. As to the jetties and works which have been raised upon the Merse grounds of Laghall, such as are contiguous to those of Cargin should be served in the same manner as has been mentioned concerning those of Cargin; but as to the rest, they are either so inconsiderable, or so placed, as to produce no sensible effect on the navigation. With respect to future works for preserving or gaining of land, provided they are so contrived as to shorten the course of the current, leaving the channel of the river of such a width, as to be wider than the medium width of half a mile above, and narrower than the medium width for half a mile below; at the same time carrying the weir fence, or advanced work, parallel to the natural direction of the current, reducing it, as near as may be, to a right line or fair curve, without sudden elbows and irregularities; laying also the banks or interior works smooth, and sloping, so as not to catch hold of and entangle the current of the tide of flood: I am of opinion, that all such works ought to be encouraged, as being advantageous to the navigation of the river.

Austhorpe, 28th Nov. 1760. J. SMEATON.

QUESTIONS

Offered by Robert Maxwell, of Cargin, to the Consideration of Mr. Smeaton.

The Merse grounds of Cargin, belonging to Mr. Maxwell, are situated on the west side of the river Nith, opposite to the Merse belonging to Mr. Johnston, of Netherwood, on the east side of the river.

The Merse of Cargin, for many years, had been greatly injured by the river, until Mr. Maxwell raised weirs, or small creals, for defending his property from future encroachment. Mr. Johnston, late of Netherwood, made works of the same nature on his side, which extend a considerable way higher up the river than Mr. Maxwell's, and opposite to works of the like construction erected on the other side by Mr. Corrie, an heritor adjoining to Cargin, on the north or upper side.

While these works were carrying on, the Town Council (as guardians of the navigation of the river) interposed their authority, and, on a visitation thereof, appointed certain parts of the works, on both sides, to be removed, as being prejudicial to the public navigation. This order having been intimated to the whole heritors concerned, they agreed to comply therewith, and became bound in writing to remove the works pointed out as being so injurious. Accordingly, Messrs. Maxwell and Corrie did remove such parts of their works as were ordered, and fixed posts or pearches on what remained, for the direction of mariners. The other heritor, Mr. Johnston, did not remove a stick or stone of his; on the contrary, his heir and successor is now insisting to have the whole of Mr. Maxwell's works removed, as being hurtful to his, Mr. Johnston's, property, and to the public navigation.

It is therefore desired that Mr. Smeaton will view the works on both sides; and, upon considering the situation and extent of them, to give his answer to the following questions.

1st. How far were these works necessary for preserving the Merse of Cargin;

and how can they be further secured, without injuring the navigation of the river, or the private property of others?—In considering this question, it is to be observed, that by the situation of the opposite grounds of Netherwood, and the higher works thereon, which extend far into the channel, the force of the land flood and ebb tide, as well as the current of the flowing tide, is thrown with much violence on the bosom of Cargin Merse, which has nothing but these works to repel the force of it; so that Mr. SMEATON will please to consider what would have been the natural consequence had such work not been made?

Question 2.—How far are the works on Cargin side prejudicial to public navigation? And please also consider whether works of this kind, raised in defence of private property, are illegal and unprecedented; and whether they tend to hurt public navigation, and injure the private property of an opposite heritor?

QUESTIONS

Offered by ROBERT MAXWELL, of Cargin, anent his Work on the Side of the River Nith, to the Consideration of Mr. J. SMEATON.

IT is desired that Mr. SMEATON, in visiting the river, will view and consider the course of the river, the floods and tide, and the situation of the grounds and works constructed thereon, upon the Merses of *Cargin* and *Netherwood*, and give his answers to the following questions.

1st. Whether from the course of the river, and the situation of the opposite ground, the Merse of Cargin is exposed to the force of the land flood and ebb tide, and also to the current of the flowing tide; and if works were not, therefore, necessary, for defending Cargin Merse from the future encroachments of the river?

2d. Whether the work already erected on Cargin Merse can hurt or prejudice the opposite Merse of Netherwood; and whether these works can be deemed illegal and unprecedented, as being injurious to the opposite grounds?

3d. How can these works be secured or improved in the easiest and most effectual manner, for preserving Cargin Merse, without injuring public navigation, or the private property of neighbouring heritors?

ROBERT MAXWELL.

ANSWER

To the Questions offered by ROBERT MAXWELL, of Cargin, anent his Works on the Side of the River Nith, by JOHN SMEATON.

ANSWER to Question 1st.—Cargin Merse, lying in the bottom, or most concave part, of a considerable loop of the River Nith, is by its situation exposed to the principal action of the flood and ebb tides, and also to that of the land floods; and the natural soil being of a very loose nature, artificial works were absolutely necessary, for the defence thereof from future encroachments of the river, as without this, the natural effect of the currents would be, to make this loop of the river still deeper, by carrying away the soil of Cargin Merse.

Answer to the 2d Question.—As Cargin Merse, notwithstanding what has been done, is still on the concave side of a deep loop of the river, the principal force of

the current is still exerted on that side; and as the opposite grounds lay upon the convex side, they cannot be sensibly affected thereby; and those above or below this concavity, are at too great a distance to be thereby affected. Works for this purpose are frequently made; and if not advanced further than what has been known to have been firm ground in the memory of man, I apprehend cannot be deemed illegal; but this part of the question more properly belongs to the laws.

Answer to the 3d Question.—By making the weirs parallel to the direction of the current, so as to make, as much as possible, a right line or fair curve, and sloping the banks, covering the same with fascines and gravel, except on such places as they can be grassed over.

J. SMEATON.

Austhorpe, Nov. 28th, 1760.

ON THE WATER-WORKS AT HALIFAX.

TO MR. SIMPSON.

SIR,

Enclosed you have a sketch of the method which I would propose for laying of the pipes of the intended water-works at Halifax, and an estimate referring thereto, which I hope will be near the matter, having spent some time in the consideration and forming thereof: however, I would not wholly rely upon my own judgment, but desire that those papers may be overlooked and considered by my ingenious friend, Joseph Knight, whose natural sagacity and acquirements in these kinds of affairs will, I am persuaded, lead him to discover and point out such oversights and mistakes as I may have been guilty of, notwithstanding the care I have taken: and I must take this opportunity of desiring, that, though the gentlemen have thought proper to consult me on this occasion, I may not be considered as any bar to his merit, but rather as jointly concerned.

It may not be amiss, however, to point out the general principle upon which I have conducted myself; and, in the first place, as the town lays very unequal in point of level, and, in consequence, a very great perpendicular pressure will lay upon the pipes, especially towards the lower parts, I have endeavoured to avoid the additional expense that naturally would arise from proportional increase of thickness, by taking advantage of such circumstances in the situation as have a tendency to relieve the disadvantages thereof; and, with this view, I have assigned the bores of the pipes in general considerably less than I should have done, in case the town had been more upon a level, because the declivity has a tendency to force the water through the pipes with greater velocity, and make them give as much water through a given orifice, as would be done by a larger pipe more upon a level, and with a lesser pressure upon it.

2dly. Considering that the supply will come from above the head of the town, and that the pipe of conduct, at its first entrance into the town, must carry all the water necessary for the supply of the whole, but that in going lower down it has only the water to convey for such parts as lay still lower; of consequence, the necessary bore of the pipe of conduct will grow less and less the further and lower it goes; but as it is a certain principle in hydraulics, that pipes become stronger in proportion as their diameters are less, when the thickness of the shell of the metal is the same, it follows, that if their bores are diminished in proportion as their perpendicular pressure is increased, the smaller pipe will be as able to sustain its

weight of water as the larger will be to sustain the pressure peculiar thereto. For these reasons, instead of adding to the weight of metal as we go lower down, I have proposed the same thickness for the main all the way; and by diminishing the diameter, and consequently the weight, have added the necessary strength, by which advantage a great weight of metal will be saved, without injury to the main design. As to the branches, I have proportioned their thickness to the thickness of that part of the main which is upon the same level, regard being had to the difference of their bores: by these means every part of the system of pipes will be equally strong with respect to the stress that will come upon it. I do not mean, however, that every part is adjusted with a mathematical exactness; for, as I have allowed every part to be considerably stronger than what may be barely called sufficient, that would be not only unnecessary, but by making every yard of pipe of different bore and thickness, would be more unreasonably troublesome in the execution. That part of the main which lays between the reservoir at the gibbet, and the back street, I have supposed of the same bore and thickness all the way, for the ease of calculation; but, in reality, I propose it to be considerably wider towards the reservoir; yet, as the pressure diminishes that way, it can be done with the same metal as the calculation supposes.

3dly. Considering, likewise, the inequality of the ground in another view, in case there should be, at any time, any defect in point of quantity furnished to the reservoir for the supply of the whole town, it is evident that the lower parts of the town would be first supplied, because the water will naturally run down hill, and accumulate in the lowest parts first; by which means the lower parts would be well supplied, when the upper parts were partially, or scarce at all supplied: and even when the reservoir would furnish as much water as the pipes could take, as the water would issue with much greater velocity from the lower cocks than from the higher: should many of the lower cocks be open together, this would still abate the issuing of the water from the higher, and especially those at a distance from the main; so that while the lower cocks were kept running in this manner, the upper ones would be but faintly supplied: for remedying of which defects, as well as others that would accrue from the sensible effects of the leakage and waste of all the cocks in the town at once, I propose to part the town into two divisions, the upper and the lower, to receive the water alternately: the upper division to consist of all the streets above the hall end, and the lower division of all below, which will be done by placing a stop-cock upon the main at * ⊕, and three others at the three principal branches at ⊕ A, ⊕ B, and ⊕ C; by which means, the * cock being shut, and A, B, and C open, the upper division will be served alone; on the contrary, the cocks A B C being shut, and the * cock open, the lower division will be served, and no part of the upper. And here it must be remarked, that I propose the two streets, called the bottom of Gibbet Lane and the Swine Market, to be served out of the branches p r, p m, and not from the main A B, B C; for otherwise, those two streets, with the upper branches dependent thereon, would be perpetually supplied, whereas the supply of every other part of the town would be intermitted, and consequently the distribution unequal.

The equality proposed hereby might, perhaps, be still greater, in case the town was divided into more divisions than two; but as the scheme would be embarrassed with a greater number of branches and stop-cocks, I was unwilling to destroy its simplicity for trifling advantages. Perhaps the division that I have proposed may not consist of an equal value of water-rents; but as this may be adjusted by propor-

tioning the time that each division shall receive the water, I would rather propose this method of preserving the equality, than by taking any other point of division, which, as the town is shaped, I think would not be so convenient.

4thly. Respecting the method of conveyance of the water from the spring to the reservoir; though I am still of opinion it may effectually be done in a gutter lined with clay and gravel; yet, considering that this gutter must be covered, and well secured from evaporation and diversion, I have, upon second thoughts, (at least for the sake of coming to an estimate), supposed this conveyance to be in wooden pipes of four inches bore, which there is no doubt will answer, and not give the water any ill taste, as the descent from Broadby Laith to the Gibbet is great enough to give the water a rapid current, consequently its time of continuance in the pipes will probably not exceed half an hour.

5thly. I have only further to observe, that I have not included the purchase in my estimate, which, added to the amount thereof, will make a sum much beyond what seemed to be imagined when I was at Halifax; and, on this account, I have been the more minute, and have enclosed a copy of the amount of each particular part of the lead-work, that in case I have inserted or omitted any street which ought to have been otherwise, a proper correction may be made; and also that the whole may be submitted to examination, from whence I flatter myself it will appear that the matter is not exaggerated. And I am, with the utmost respect to the gentlemen promoters of this scheme,

SIR, Your most humble Servant,

J. SMEATON.

P. S. Please to tell my friend, Mr. STANSFIELD, that the improvements I supposed might be made in fulling as well as other mills, when this matter came in question on the Calder, is no longer a matter of theory; and, contrary to the determination of Mr. BANKS, *that a fulling-mill is a machine so simple, that it is not capable of any farther improvement,* a fulling-mill that has been erected from one of my plans, in dry times, goes with less than a quarter of the usual quantity; and in freshes goes with 3 feet 8 inches tail water; though the greatest difference between head and tail water, when the last is most down, in dry seasons, never exceeds 4 feet 6 inches.

ESTIMATE FOR THE WATER-WORKS AT HALIFAX.

	£.	s.	d.
To expenses in walling and securing the spring head	30	0	0
To piping from Broadby Laith-spring to the Gibbet, being two miles, to be wood pipe four inches bore, laying and completing, at 5*s.* per yard	880	0	0
To erecting a water-house and reservoir near the Gibbet	200	0	0
To 653 cwt. of lead piping in the main, leading from the reservoir to Smithy Stake, soldering work, laying, and making good the streets, at 1*l.* 4*s.* per cwt.	783	12	0
To 931 cwt. in the branches at ditto	1117	4	0
To four large brass stop-cocks and a valve, at 4*l.* each	20	0	0
	3030	16	0
To unforeseen expenses, at 10 per cent.	303	0	0
	3333	16	0

LONDON, 14th February, 1761.

Place.	Bore.	Thickness.	Length.	Weight.	
			Ch. L.	lbs.	
* A	3½	½	12 10	25,555	
A B	3⅜	½	2 80	5,914	
B C	3¼	½	5 85	11,624	
C D	3	½	5 30	9,864	
D E	2¾	½	3 13	5,433	
E F	2½	½	3 18	5,123	
F G	2¾	½	3 10	4,604	
G H	2	½	3 68	5,005	
			39 14	73,122	C. qrs. lbs. = 652 3 14

N.B. The mark * is supposed to be placed at the Gibbet.

Branches.	Bore.	Thickness.	Length.	Weight.	
			Ch. L.	lbs.	
A a	2½	⅜	4 81	5,714	
a b	2¼	5/16	2 52	2,223	
B b	2¼	5/16	6 00	5,292	
C b	2¼	⅜	7 23	7,852	
b c d b	2	¼	13 00	7,937	
e f	1⅜	¼	1 92	1,042	
g h i	1⅜	5/16	8 62	6,141	
k l	2	5/16	2 76	2,201	
l m	1⅜	5/16	5 00	3,562	
n o	1¼	¼	2 85	1,354	
p q	1⅜	¼	4 00	2,171	
r s	1½	¼	1 75	831	
p r	2¼	5/16	2 90	2,558	
r m	2¼	⅜	6 00	6,516	
t v	2¼	⅜	3 20	3,475	
v w	2	5/16	8 00	6,378	
v x	1⅜	5/16	4 10	2,921	
v E	1½	5/16	5 10	3,200	
D y	2¼	7/16	3 00	3,870	
y z	2	⅜	5 30	5,215	
R V	1½	5/16	1 50	941	
S T	1½	5/16	2 60	1,632	
E N O G	1⅜	⅜	9 20	8,115	
Q P	1½	5/16	2 40	1,506	
H M	1½	⅜	3 60	2,808	
H I	1⅜	7/16	2 17	2,282	
I K K L	1½	7/16	7 00	6,528	
			126 53	104,265	C. qrs. lbs. = 930 3 21
			39 14	73,122	= 652 3 14
			165 67	177,387	1583 3 7

PROPOSALS

For building an Engine for raising Water eleven Feet from the Well or Reservoir, into the Piece of Water in the Gardens of Her Royal Highness the Dowager Princess of Wales, at Kew, to be worked by one large or two light Horses.

THE following things are supposed to be done at the expense of her Royal Highness. The drain or gutter, leading from the engine to the Chinese house to be lowered four feet; the ground to be cleared and levelled for the engine to stand upon; the earth to be wharfed up with brick-work; the well cleaned, and the brick-work repaired, where necessary; and, in case it is thought expedient to underpin the groundsill of the shade with brick, the materials to be led from the river to the place, and the labourers to assist in lifting and digging what may be required during the setting up.—The engine to work with an Archimedes screw, 2 feet 8 inches diameter, and 24 feet long; the shade for the horses to be 30 feet from out to out, and the mean diameter of the horse track 24 feet.

This engine to raise 1200 hogsheads in four hours, with one large horse, or two light ones, such as have heretofore been used.

A small pump, to be worked occasionally by the engine, for raising water from the gutter to the cistern, in the kitchen garden.

The whole of the machinery and frame-work thereof, with the shade for the horses' walk, and a cover from the screw, with a cistern and sluice at the foot thereof, to be completed in the most substantial and workmanlike manner, for the sum of one hundred and fifty pounds.

THE REPORT

Of JOHN SMEATON, *Engineer, concerning the practicability, &c. of a Navigable Canal from Wilden Ferry, in the County of Derby, to King's Bromley Common, near Litchfield; and from thence in several Branches, the first leading to Longbridge, near Burslem, the second to Newcastle-under-Line, the third to the City of Litchfield, and the fourth to the River Tame, at or near Fazeley Bridge, near Tamworth, all in the County of Stafford, as projected by Mr.* JAMES BRINDLEY, *Engineer.*

HAVING, in company with Mr. BRINDLEY, and Mr. HENSHALL, land surveyor, in the month of November, 1760, carefully viewed and considered the tracts of ground, through which the canal above-mentioned and its branches are proposed to pass and compared the same with the plans and levels produced by Messrs. BRINDLEY and HENSHALL; and also viewed the course of the rivers (Trent and Tame), as well as the several brooks, streams, water-courses, and whatever else seemed principally to relate to the above-mentioned project, it appears to me as follows:

1st. That the waters that are or may be collected into the brooks, at the head of the proposed canal and its several branches, are respectively sufficient to supply the same with water; and that the canal and its branches, as projected by Mr. BRINDLEY, are practicable, and may be executed at the several expenses contained in an estimate bearing the same date as this report.

2d. That, as the river Trent appears to have few pools naturally navigable, in proportion to its extent, and those of no great length, but, on the contrary, abounds with shoals, is in many places very winding, in general runs in a shallow channel, and is subject to continued floods; in consequence, a new canal will answer the purposes of a navigation, in the present case preferable to carrying the same more generally through the mother river, and which, for a great part of the tract in question, is impracticable at any tolerable expense.

3d. That, in particular, the present navigable part of the Trent, between Wilden Ferry and Burton, is so much obstructed by shoals and scours, that the purposes thereof would be much more effectually answered by the canal projected by Mr. BRINDLEY.

4th. That the tracts of ground through which the canal above-mentioned and its branches are proposed by Mr. BRINDLEY to pass, are well chosen, and, for the greatest part, well adapted by nature for such a purpose, and as little injurious to private property as the nature of such a work will admit of; Mr. BRINDLEY having judiciously designed the course thereof to pass through a great number of level commons and waste grounds, and, in general, through the most barren lands that could be found in anywise to agree with the course thereof.

5th. That a branch from the canal to Longbridge may be conducted upon a dead level from near the town of Stoke to the town of Newcastle, as laid down in the plan.

6th. That a canal from King's Bromley Common may be conducted up the

valley of Litchfield Brooks to the city of Litchfield, but at a very moderate charge, to the tail of Stow Pool.

7th. That a canal being conducted upon a level from some proper point of the main canal, at or near King's Bromley Common, the same will meet the valley of the Tame at or near Fazeley Bridge; and, by inverted locks, a communication may be formed, and the navigation may be carried by that river to the borough of Tamworth, the waters being pounded up thither by the mills at Tamworth.

8th. That the branch of the canal proposed to be carried to Longbridge is capable of being extended so as to join the navigable river that falls into the west sea; for it is but a little above two miles from Longbridge, to a meadow which lies between two hills near Harecastle, in which meadow the waters that run into the west sea divide from those that make their way into the east, and which, therefore, may be called the point of partition. The grounds between Longbridge and this point lie with a gentle declivity, and, according to a level taken by Mr. HENSHALL, this point of partition is elevated above that of Longbridge a little more than 90 feet; but as one-third part of this ascent lies within a quarter of a mile of the summit, and as the ground there appears to be suitable, a considerable part of this ascent may be avoided by a deep cut through the summit, which will be of a moderate length, as the ground seems of the same quality, and to fall away much in the same manner on the west side as on the east; and as, according to the report of those who know the grounds, particularly the meadows on the west side, are nowhere interrupted by rocks or other remarkable obstructions, a canal is by consequence as practicable from the point of partition westward as it is from the same point eastward; and the distance is not near so great to the navigable rivers on the west, as on the east. It only remains that probable means be shewn of supplying this additional canal at the point of partition with water; for if this is done, the lower parts will be supplied of course. In respect whereof it must be observed, that the point of partition lies greatly under the level of the adjacent hills, and, consequently, the springs issuing from such hills may be conducted thither, and all the water upon the more elevated grounds may be intercepted for several miles round, in order to supply a reservoir in a proper place, above the level of the point of partition. These springs will be further assisted by water issuing from the coal-pit drains that now are, and hereafter will probably be multiplied, as the grounds hereabouts abound with coal, the greatest part of which is at present ungot; but should all these resources in a dry season prove too little, the navigation may be supplied with water by the help of a fire-engine, to return the waters from a lower level, where the collection of springs may at all times be sufficient; so that the water may be used as many times over as may be needful.

9th. That, from the best information, it appears, that the present navigation between Wilden Ferry and Gainsborough is much obstructed by shoals and scours, insomuch that in several places, in the common state of the river in dry seasons, there is not above 8 inches depth of water; and that, at such times, without the aid of flashes from King's mills upon the Trent, and the lowest mills upon the Derwent, the navigation would then be impracticable.

10th. That, for these reasons, the purpose of the canals before mentioned will not be fully and completely answered, without an amendment of the navigation between Wilden Ferry and Gainsborough, either by an extension of the main canal from Wilden Ferry to the tide's way, or by some other means that may effectually answer the purpose; nevertheless, I am of opinion,

11th. That the purpose of the canals already mentioned will in good part be

answered, even should the obstructions of the navigation between Wilden Ferry and Gainsborough remain as they are; for, notwithstanding those obstructions, a large quantity of goods is navigated up this part of the river with advantage, and if a canal is completed, on the present plan, to Wilden, it will be still better worth while to conquer the difficulties attending this part, in order to get into a clear and complete navigation, that will carry goods without obstructions into the heart of the kingdom, according to the printed plan; and even across the kingdom, if the scheme should take place in its full extent; and whenever that is the case, it is not to be doubted but means will be found of rendering the navigation between Wilden Ferry and Gainsborough equally perfect with the rest.

12th. In order, therefore, that the boats which at present navigate upon the Trent may navigate freely upon the new canal, I am of opinion with Mr. BRINDLEY, that the canals ought to be about 8 yards wide at the water line; and that the new canal may be of a suitable depth, when the obstructions below Wilden are removed, the same ought to be 2 feet 6 inches deep of water upon the fording-places, which ought to be shoalest, and 3 feet or 3 feet 6 inches in other places, to allow for mud and sufficient freedom for the vessels; and this depth will be of advantage, notwithstanding the want of depth of water below, because the loading of two vessels from Gainsborough may be put into one at Wilden, and the loading of two vessels at Wilden brought in one from above.

13th. That the lock-gates being made water-tight, as they are capable of being made, no mill can be deprived of any water. Further, that one lockful to each boat, which, on exact calculation, is found to be a very inconsiderable quantity in proportion to what is necessary to work a mill for twenty-four hours; the evaporation from the surface of the canals, and leakage through the banks into the back drains, scarcely deserve mention with respect to their effect on the mills. As to fisheries, they cannot in anywise be affected, because the waters in the canals being nearly stagnant and closed by the lock-gates no fish can pass either way.

14th. That the public road being supplied with sufficient carriage-bridges, the water-courses with underground passages, the communication between commons and private properties by a sufficient number of fording-places, well paved and sloped, and no where above 2 feet 6 inches deep, and the banks, whenever the water of the canal is even with or above the natural soil, to be furnished with sufficient back drains to convey any leakage of the water that may happen, to its proper and natural place of discharge: I say, things being thus provided for, public and private roads, all necessary communications between grounds, and water-courses, will not only be preserved, and the grounds themselves freed from damage, but, on the other hand, many lands will be greatly benefited by having plenty of good water for cattle, &c.

AUSTHORPE, 11*th July*, 1761. J. SMEATON.

GENERAL ESTIMATE

For making the Canals and Works for completing the Navigation and Branches, referred to in Mr. SMEATON'S Report, upon Principles of Estimation settled between Messrs. SMEATON and BRINDLEY.

	£.	s.	d.
1st. To making the main canal from Wilden Ferry to King's Bromley Common, being, in length, 25 miles; the perpendicular ascent, 110 feet; with 19 locks thereon	32,054	10	0
2d. To making the great western branch, from King's Bromley Common to Longbridge, between Burslem and Newcastle-under-Line, being, in length, 30¼ miles; perpendicular ascent, 166¾ feet; with 28 locks thereon	45,884	15	0
3d. To the small branch out of the last, proceeding from Stoke to Newcastle, being, in length, 3½ miles; upon a dead level, without a lock	3,806	6	0
4th. To making the Litchfield branch, from King's Bromley Common to the tail of Stowpool near Litchfield, being, in length, 2½ miles; perpendicular ascent, about 18 feet; with 3 locks thereon	3,995	9	0
5th. To completing the above into Litchfield mill-pool, being about half a mile; and perpendicular ascent, about 30 feet; with 5 locks thereon	3,029	18	0
6th. To making the Tamworth branch, from King's Bromley Common to Fazeley Bridge, near Tamworth, being, in length, 10 miles; upon a dead level, without a lock	9,431	12	0
7th. To completing the above by a cross canal into the river Tame, being, in length, half a mile; perpendicular descent, 16 feet 10 inches; with 3 locks thereupon	1,995	12	0
	100,198	2	0

AUSTHORPE, 11th July, 1761.

J. SMEATON.

THE RIVER WEAR.

The Report of J. SMEATON, concerning the Situation of the first Lock of the River Wear.

HAVING, in obedience to the order of the Commissioners, at their last meeting on the 2d May, 1761, re-examined, as well the situation staked out by me in November last, as the situation lately proposed by the Gentlemen Coal Viewers, who viewed and marked out the same 176 yards higher up the river than the former; and having carefully examined the river in both places, and, also, at intermediate distances, I am humbly of opinion as follows:—

1st. That the erection of a lock at the place marked out by me in November last, cannot have the least tendency to prejudice the coal-works underneath; for though the workings underneath are ever so irregular, and though a thrust should have been brought on two pillars 30 yards to the north of the lock, yet while those pillars are capable of supporting the river Wear, they are capable of supporting the lock. Nor will the placing of a lock there in any wise tend to weaken the body of solid matter interposed between the bottom of the river and the bed of coal; for the sill has been found in the bottom of the staples at 21 feet from the surface of the ground, and it may be necessary to sink the foundation of the lock 24 feet below the same surface; yet, as the staples are sunk 18 feet, or thereabouts, more northward than the utmost limits of the lock wall; and since it appears, that at the verge of the water, and within the river, the sill lies as low, and, in many places, much lower than the intended foundation, there does not appear to be any occasion to sink into the sill at all; and yet, in case there should be occasion to cut half a foot, or even one foot on the north side, into the sill, by way of bringing the same to a level (the sill appearing from the staples to rise with the hill towards the north), yet as this will be replaced with matter much more compact and impenetrable to water than the sill itself, it is not easy to conceive, that this can in the least prejudice the resistance of

a body of matter 12 or 15 fathom in thickness, being so much down to the workings of the five quarter coal.

2dly. That it is practicable to build a lock at the place marked out by the Gentlemen Coal Viewers, 176 yards higher up the river than the former; but that such situations will be attended with the following additional disadvantages.

1st. It appears, that, the sill lying, at the last mentioned place, at a medium, 1½ feet lower than the foundation of the lock, the carrying the foundation one foot and a half lower than necessary will not only be attended with a considerable charge, but being a quicksand down to that depth, the drainage of the water, and securing the sides of the lock-pit till the bottom is finished, will be much more difficult and expensive also. And, lastly, as there will be a necessity of making a channel for the passage of the vessels on the north side, into the lock, from the tail of the lock, as proposed in its former situation, it will, therefore, be necessary to dredge the whole distance of 176 yards; and not only that, but to secure the side of the channel next the river with a proper fence, to prevent its being filled with the silt of the river upon the first flood; and, as this is a work capable of estimation, I have hereto annexed an Estimate thereof.

DURHAM, 2d June, 1761. J. SMEATON.

ESTIMATE

For the probable Expense of clearing the Channel of the River Wear 176 *Yards, being the Distance of the Situation of the first Lock, as proposed by the Gentlemen Coal Viewers, above the Situation as staked out, in November* 1760, *by* JOHN SMEATON.

	£.	s.	d.
To 176 yards of water-tight wearing, at 4*l.* 10*s.* per yard	792	0	0
To fixing a temporary cross dam, at the tail of the Wear, and taking the same away	10	0	0
To drainage of the water while the silt is getting out, supposing 30 days, at 6*s.* 8*d.* per day	10	0	0
To getting out 1760 cube yards of matter, at 6*d.*	44	0	0
	856	0	0
To unforeseen accidents, at 10 per cent.	85	12	0
	941	12	0

N.B. The 176 yards of water-tight dam are intended to be executed with oak, in a durable manner, so as to remain a fence against the silt of the river.

GENERAL ESTIMATE

For completing the first Lock and Dam at or near JACKSON'S, *near Harraton, upon the River Wear.*

	£.	s.	d.	£.	s.	d.
To clearing Briddick Ford, and two other shoals between that and Mr. Lambton's engine drain				500	0	0
To wearing and dredging 176 yards from the bottom of the caunch below Jackson's Ford, up to the tail of the lock, as per former estimate	941	12	0			
To probable expense in the foundation of the lock at Jackson's Ford, superior to that in its first intended situation	258	8	0			
				1200	0	0
To expense of building the lock in its first situation	900	0	0			
To ditto of the dam adjoining	600	0	0			
To cutting the ground drain of the water and temporary dam to both, at least	500	0	0			
				2000	0	0
Expense of the navigation from Briddick Ford to New Bridge				3700	0	0

N.B. 1st. The expense of the machines, shops, utensils, &c., together with the necessary materials for beginning the work, will be, at least, 1000*l.* and if the work goes on no further than the first lock, there will be, at least, 500*l.* lost by the articles just mentioned, which otherwise would serve for the whole.

THE RIVER CALDER.

Comparative Estimate for carrying on the Navigation of the River Calder by Means of a long Cut from the Figure of 3 *Lock at* F, *to above Dewsbury low Ford at* H, *and of carrying it partly by the River and partly by* 3 *short Cuts as in the general Plan.*

ESTIMATE FOR A MILE OF CUT.

	£.	s.	d.
To 14 acres of land at 50*l.* per acre	700	0	0
To cutting, at a medium, 6 feet deep, 16 feet wide at bottom, and 36 at top, at 3*d.* per yard cubic	381	7	0
To sodding and batting down the banks, and sowing them with hay-seeds, at 2*s.* per rood	41	16	0
To extra work in forming 8 passing places, at 5*l.* each	40	0	0
To 14 quarters of hay-seeds, at 7*s.* per quarter	4	18	0
Expense of land, cutting, &c. per mile	1168	1	0

ESTIMATE FOR THE NAVIGATION BY THE LONG CUT.

	£.	s.	d.
To 2¼ miles at 1168*l.* 1*s.* per mile, land and cutting	2628	2	0
To extra work in digging two lock-pits, at 30*l.* each	60	0	0
To 3 carriage-bridges of wood, at 60*l.* each	180	0	0
To 3 tunnels for draining, at 10*l.* each	30	0	0
To 1 lock building, at 600*l.* and 1 ditto, at 400*l.*	1000	0	0
To 1 low dam at the head of the cut	300	0	0
To extra work in banking near Milbank Quarry, and cutting through a rising ground near the Warren House	150	0	0
	4348	2	0
To contingencies on the above articles, at 10 per cent	434	16	0
Total	4782	18	0

ESTIMATE FOR THE NAVIGATION AS BY THE GENERAL PLAN.

	£.	s.	d.
To ⅞ of a mile of cut, at 1168*l.* per mile	1022	0	0
To extra work in digging 3 lock-pits, at 40*l.* each	120	0	0
To 3 tail-bridges for the locks, at 20*l.* each	60	0	0
To one tunnel for drainage, at 10*l.*	10	0	0
To 2 locks building, at 600*l.* and 1, at 400*l.*	1600	0	0
To 1 dam, at 500*l.* and 1 ditto, at 300*l.*	800	0	0
To extra expenses in crossing the Calder	100	0	0
To extra expense in removing the new mill cloughs, and setting piles to prevent the boats going over the dam	100	0	0
	3812	0	0
To contingencies on the above articles, at 20 per cent	762	8	0
Total	4574	8	0

TETNEY HAVEN NAVIGATION.

The Report of JOHN SMEATON, *Engineer, concerning the practicability, &c., of a scheme of navigation from Tetney Haven to Louth, in the county of Lincoln, from the view taken thereof in August* 1760, *as projected by Mr.* JOHN GRUNDY, *Engineer.*

HAVING carefully examined the scheme of navigation proposed by Mr. JOHN GRUNDY, for making a navigable canal from Tetney Haven to the upper end of Avingham out-fen; and from thence to join the river Lud, or Louth river, between Ringer's drain and Avingham mill; and from thence, partly by the course of the river, but chiefly by a new canal, up to New Bridge, at or near the town of Louth; and having carefully compared the said scheme with the lands through which the aforesaid navigation is proposed to pass, and also examined as well the principal water-courses, eau-moats, and out-falls, as the havens and communications with the sea and river Humber, which relate to the abovesaid scheme, I am of opinion as follows:

1st. That Tetney Haven is the most proper out-fall for a navigable canal, as being both safest and deepest, and affording a communication with the inland navigations of Yorkshire and the Trent, for flat-bottomed barges, without going to sea, which, at some seasons of the year, would be dangerous or impracticable.

2d. That the course of the intended canal, as laid down in Mr. GRUNDY's plan, from Mr. YOUNG's warehouse, near Tetney Haven, to its junction with the Louth river, between Ringer's drain and Avingham mill, is the most eligible position, both for the purpose of navigation and drainage, as passing in general through the lowest grounds.

3d. That the rest of the intended navigable course, from the junction of the canal with the river, as aforesaid, to New Bridge, near the town of Louth, as marked out in the said plan, is also very proper, and does not seem likely to be attended with any particular prejudice to the owners of the adjacent grounds, more than what is inseparable from the nature of the undertakings of this kind.

4th. That the owners of the low grounds, that are liable to be affected by the Tetney river, will, in particular, receive great benefit from this undertaking; because,—

5th. The water of Tetney river being received into the navigable canal before it meets the sea-sluice or lock, as the water of this canal is, by the said proposed scheme, to be kept constantly lower by 1 foot than low water mark of the Tetney river, under Sheep's Bridge; it follows, that the surface of Tetney river will, at its out-fall into this canal, be kept at least one foot lower than it could be by placing a sea-sluice at or near Sheep's Bridge upon the present course of the river.

6th. I am of opinion, that the carrying the navigation up the Tetney river further than Sheep's Bridge, will no way contribute to the more effectual drainage of the Tetney lands, and will carry the canal considerably out of its due course; but that a navigation for lighters and small vessels may be separately made up the Tetney river to Tetney, at a small expense.

7th. That the surface of the water of the canal, being kept one foot lower than the point of low water at Sheep's Bridge, will be lower than the surface of the water in all the drains that it will intersect; and, consequently, that the water of those drains, being turned into the canal, will afford a means of draining those lands more effectually, or may, occasionally, be kept up at their present level by small shuttles, or stops, near the side of the canal.

8th. Where the passages for waters from springs, for watering grounds and other purposes, are intersected by the intended canal, and are desired to be continued in their present course, they may be continued by subterraneous passages or tunnels, as has already been observed in Mr. GRUNDY's Report.

9th. That the principal conveyance of spring-water, next to Tetney river, appears to be that of the North Coates Fleet, the surface of which lies higher than the surface of the intended canal, and, therefore, will discharge itself into the same; consequently, if there should be any objection from Tetney against supplying the navigation in dry seasons from their river, such supply may be had from North Coates Fleet, or other sources, having communication with the canal upwards.

10th. I am further of opinion, that whichever of these ways are thought most eligible, that the sea-lock ought to be provided with ebb-gates, or gates pointed landward, as well as seaward, that the water may be retained in the canal to its due height, and to enable the vessels to pass at all times when there is depth of water without the sea-lock; it also appears to me, that the purpose of the lock will be as effectually answered by taking in one vessel at a time as by taking in two.

11th. That in case the several parishes concerned could be agreeable that the redundance of one parish should contribute to the defects of another, this canal would be the best means of performing it; for a part of the water of North Coates Fleet, or Tetney river, being admitted into the canal, all those grounds contiguous, or which might be brought to communicate with the canal, quite up to Avingham out-fen, might, by proper drains, be supplied with spring-water.

12th. That, according to the modern practice of building locks, they are capable of being made and preserved water-tight, wherever this circumstance is necessary.

13th. That, according to this scheme, no water will be turned away from Ringer's drain and the eau-moats, except what is necessary to fill a part of the first lock upon the canal near the upper end of Avingham out-fen.

14th. That on the 7th day of August, 1760, after the driest season that has been known in the memory of man, I carefully examined the discharge of water by the Louth river in 24 hours at Thorold's mill, being the first below the new bridge at Louth, and compared the same with the discharge at Avingham mill, and found the quantity such as to fill the said first lock, near the upper end of Avingham out-fen, to the height required for the passage of a barge 200 times in 24 hours. So that, even in the driest seasons, the quantity of water expended by the navigation will be so very inconsiderable, in proportion to what will still remain, that the difference will be quite insensible to the occupiers of lands.

15th. That there is a possibility, that even this inconsiderable loss of water may be totally prevented in scarce water times; but at an expense to the undertaking which so inconsiderable a quantity does not seem to merit.

16th. That the course of the river from the place of junction of the canal therewith to the town of Louth, being narrow, crooked, and generally shallow, with level meadows on one or both sides, and scarcely any part of it in a navigable state; I apprehend it will be more eligible and less expense to dig a new canal, with locks upon the same, at proper distances, than to pursue the old course of the river; and that the scheme above referred to is very proper for this purpose.

17th. That the rise of the river, from the place of junction of the canal with the river, as aforesaid, to Keddington old mill, is very gentle, being, in length, about 2¾ miles, and rise, about 24 feet, according to Mr. GRUNDY's survey; from thence to a meadow, a little below the leather-mill, the ascent is more sudden, being 11½ feet in

three quarters of a mile; and from thence to the new bridge at Louth still more, being about 21 feet in the same space.

18th. I am, therefore, of opinion, that the distance of three quarters of a mile from the leather mill, to the new bridge at Louth, will be, in proportion to the distance, the most expensive part of the undertaking; but that a considerable sum will be saved by terminating the navigation at Kiddington old mill, to which place it may be brought on very moderate terms.

Austhorpe, July 14th, 1761. J. SMEATON.

GENERAL ESTIMATE

Of the Expense of making a Navigation from Tetney Haven to Louth, according to Mr. Grundy's Plan.

	For barges, with canals wide enough for two to pass in all places.	For barges, with canals for one, with passing places.	For lighters drawing two feet water.
From Tetney Haven to the new bridge at Louth	£15,590	£13,686	£10,884
From Tetney Haven to the meadow below the leather mill	12,968	11,241	8,931
From Tetney Haven to Keddington old mill	11,098	9,481	7,589
From Tetney Haven to the top of Avingham out-fen	7,853	6,566	5,312

N.B. In the above estimate the expense of procuring an act of parliament is not included. The marsh land is estimated at £10, and the meadow at £20 per acre; the ground covered is reckoned at half value, or, what is the same thing, at half quantity; the quantities to be purchased are as under, so that whatever alteration there may be in the price now supposed, the difference may be applied without affecting the other articles.

	2 Barge canal.	1 Barge canal.	Canal for lighters.
	acres.	acres.	acres.
Marsh Lands	57	45½	40
Meadow Lands	32½	26	22¼
Total Acres	89½	71½	62¼

Austhorpe, July 14, 1761. J. SMEATON.

RIVER WITHAM.

The Report of MESSRS. JOHN GRUNDY, LANGLEY EDWARDS, *and* JOHN SMEATON, *Engineers, concerning the present ruinous State and Condition of the River Witham, and the Navigation thereof, from the City of Lincoln, through Boston, to its outfall into the Sea; and of the Fen Lands on both Sides the said River; together with Proposals and Schemes for restoring, improving, and preserving the said River and Navigation, and also for effecting the Drainage of the said Fen Lands: to which is annexed a Plan and proper Estimates of the Expenses in performing the several Works recommended for those Purposes.*

INTRODUCTION.

THE river Witham, from Lincoln to Boston, falls in a crooked course through the low grounds of the several lordships following, on the south side thereof, viz: Lincoln, Canwick, Washinborough, Branston, Potter-hanworth, Nocton, Dunston, Metheringham, Blankney, Marton, Timberland, Timberland-Thorpe, Walcot, Billinghay, Billinghay-Dales, and Dogdike to Chappel Hill; and on the north side through the low grounds of Monks, Greetwell, Willingham, Fiskerton, Barlings, Stainfield, Bardney, Southrey, Tupholm, Bucknall, Horsington, Stixwold, Swinesike, Woodhall, Thornton, Kirkstead, Tattershall, and Conningsby; and from the said Chappel Hill it runs, in a very crooked and meandering course, betwixt the large and extensive fens called Holland Fen on the south, and Wildmore and West Fens on the north, to Room's Hall, and from thence, through some inclosures, to Boston, and from Boston, through the High Marshes, into the great bay, called Metaris Estuarium. The distance from Lincoln to Boston, by the old course of this river, is about 43 miles.

This river has formerly been a very good navigation from its outfall at the Scalp to Boston (which is about 4 miles), sufficiently capacious and deep to navigate large ships into the town, and from thence to convey barges, keels, and other vessels, to Lincoln, almost at all times in the year; and a very extensive and advantageous branch of commerce has, till of late years, been carried on by the said river, to the great benefit and advantage, not only of the city of Lincoln and town of Boston, but also of the several towns and villages adjoining upon, and contiguous to it, through an extent of country for many miles in length and breadth.

It was also, when in the aforesaid state and condition, the mother river and outfall for the drainage, not only of the low grounds and fens aforesaid, but also of the low grounds of North Kyme Fen, South Kyme Fen, Hart's Grounds, Great and Little Beets, Rakes, Heckington Fen, Lady Frazer's 600 acres, Ewerby, Howell, Asgarby, Great and Little Hales, Brothertoft, Anwick, Ruskington, Dorrington, Digby, Mareham, Hundle House, Revesby, Middleham, Moor House, Meer Booth, Hermitage, Newholme, West House, Langrike, Frith Bank, Langworth, Swinecote, Stickford, and Stickney; and also of many other low grounds and fens lying more distant and remote therefrom, (but having their outfalls for drainage into it) containing in the whole, by estimation, upwards of 100,000 acres.

This once so flourishing river and country have, for many years last past, been falling into decay, by the banks of the said river being suffered to become ruinous, and incapable of sustaining and confining the water in times of high country floods, so that those flood waters, which were necessary and used heretofore, by their velocity and weight, to cleanse out the sand and sediment brought up by the tides, have been, and now are, suffered to run out of their ancient and natural course, and expand

over the adjoining fens and low grounds, whereby those sands, for want of a reflowing power of adequate force to carry them back, have now so much choked up the haven from Boston to the sea, that for several years last past the navigation thereof has been lost for shipping, and it is now become even difficult for barges of about 30 tons burden to get up to the town in neap tides. And for several miles above the town of Boston, the said river is totally lost; insomuch that its bottom is, in many parts, some feet higher than the adjoining low grounds, and the site thereof converted into grazing and farming purposes.

This mischievous effect has not only been destructive to the navigation of that river, but also to the drainage of the aforesaid vast tracts of fens and low grounds, by reason that many of the mouths of the inward drains, dikes, and sewers, which should have their outfalls into this river, are totally landed up and lost, and have not run at all for many years into it; and the few that have their outfalls so low as Boston, and below it, are nevertheless, in all dry seasons, so much choked up and obstructed, that the said fens and low grounds must be, in some parts, considerably under water, before they can have vent through their outfalls into the said river or haven, whereby the flood-waters lie so long stagnant thereupon, as to destroy the herbage thereof, and render them not only useless and unprofitable, but also extremely noxious and unwholesome to the adjacent inhabitants.

To find out proper and necessary expedients to improve this river and fens, surveys and levels were taken some years ago, from Wiberton Roads to Lincoln, not only along the course of the said river, but also on the adjoining fens and low grounds, to compare their different surfaces, both with respect to the said river and their outfalls to sea; in consequence of which, a scheme was formed and published in the year 1744, by Messrs GRUNDYS, Engineers, recommending such expedients as, to them, at that time, appeared proper for effecting the above desirable purposes; upon which, several meetings have from time to time been held, to consider this and other schemes, and many clauses were prepared for a bill, particularly at a meeting held at Lincoln, in November 1753, and others subsequent thereto.

In the year 1760, Mr. LANGLEY EDWARDS was employed to make views of the premises in question, and since then Mr. GRUNDY, the son, has re-surveyed the river and fens, and both have made their several reports thereupon; which said surveys, levels, resolutions, and reports, being duly considered, and a fresh view taken of the river and fens in October 1761, by Messrs. GRUNDY and EDWARDS, in conjunction with Mr. JOHN SMEATON, Engineer, we, the said JOHN GRUNDY, LANGLEY EDWARDS, and JOHN SMEATON, are joinly of opinion as follows, viz:

REPORT.

In the first place, it appears to us, that from the great tendency of this river to silt, and the great advance the same has made in the space of 20 years, that, in all human probability, within the compass of a few years more, not only the outfalls of the present effective drains near Boston will be totally lost, but the whole river landed up, unless sufficient measures are speedily taken to prevent it; and the most eligible means for so doing, we conceive, will be to make and preserve a mother river, of sufficient depth and capacity to effect a general drainage of the several fens and low grounds aforesaid, and also to restore this lost navigation, from the sea through Boston to Lincoln, and into the Brayford Meer (which has a navigable communication

through the Fossdike with the river Trent), upon the following principles, and by the following methods, viz:

1st. That the new proposed river be made in the shortest direction that can be, consistent with the lowest surface of the country, considered in a medium proportion, and most convenient for receiving the waters thereof.

2d. That its dimensions be such as to be capable of receiving and discharging, not only all the upland waters, but also all those of the several branch rivers and drains that fall into it.

3d. That its banks be made of sufficient strength and height to confine the flood-waters within them, and to force them down to sea, without overflowing the adjoining fens and low grounds.

4th. That its bottom be made with a regular declivity from Lincoln to the sea; which, according to the levels, will be at a medium near 5½ inches per mile.

5th. To collect all the living waters into this new river that can be obtained; by scouring out and embanking all side rivers, rivulets, and brooks, that bring down such living waters out of the high country into it, in order to obtain a reflowing force that shall be capable of driving out such matter as is left by the tides, by which means only the outfall below can be preserved open and clean.

6th. To stop the tides from flowing at all into this new river, that its depth and dimensions may be preserved.

7th. That this work shall be so constructed that navigation may be carried thereon, so as in no wise to interfere with or prejudice the drainage.

8th. That the necessary works be constructed to retain the fresh water, to be made use of as occasion shall require, for the well watering the said fens and low grounds in dry seasons for the use of cattle, &c.

And, lastly. That no salt water be admitted into the mother river, or drains above Boston, by means of the proposed navigation.

THE SCHEME FOR THE DRAINAGE.

1st. To erect a sea-sluice for stemming the tides between Lodowick's Gowt and Boston Bridge; and we recommend a piece of ground, commonly called Harrison's Four Acres, at (A) (see the plan for that purpose), the floor whereof to lie level with low water-mark at Wibberton Roads, and its neat capacity, or clear water-way, to be 50 feet, with three pair of pointing doors to the seaward, to shut with the flow of the tides, and drop or draw-doors on the land side, to be shut occasionally, to retain fresh waters in dry seasons; the top of these draw-doors to be gaged to such a height as to retain the water of the river not higher, at ordinary seasons, than 2 feet below the surface of the lowest lands that drain therein.

2d. To make a new cut from this sluice to or near Anthony's Gowt (A B) in as straight a direction as the nature of the ground will admit of; 80 feet broad at the top, 50 feet broad at the bottom, and 10 feet deep: and from the said place, at or near Anthony's Gowt, to make a new cut (in as straight a direction, also, as the nature of the ground will admit of) through Wildmore Fen to Chapel Hill (C), at a medium, 66 feet wide at top, 50 feet wide at bottom, and 8 feet deep. The earth coming out of this new river to be disposed of in forming banks, which are proposed to be set 40 feet distance from the brink of the river.

3d. The river, from the upper end of this new cut, at Chapel Hill, to Lincoln, is proposed to be continued in its present course; but the shallow parts thereof to be scoured out and deepened, where necessary, so as to be every where of the following dimensions at a medium, viz.

For three miles and a half above Chapel Hill, 60 feet broad at the top, 40 feet broad at the bottom, and 5½ feet deep below the present bottom. From thence to Washingborough lordship, above Branston Dyke (being about 12½ miles), this river (having the waters of several rivulets and brooks to receive within those limits) should be 40 feet wide at the top, 30 feet wide at the bottom, and 2 feet deeper than its present bottom, at a medium. From hence to Stamp End, in Lincoln (being about 10 miles), to deepen the shoals in the old river, so as to be 30 feet broad at the top, 24 feet broad at the bottom, and 2½ feet deeper than they now are on an average.

4th. To make and erect one wagon-bridge at D, and two horse-bridges (E and F), with necessary gates and fences for continuing the roadway and other communications, and for dividing the Wildmore and West Fens from Holland Fen.

5th. To scour out and embank Kyme Eau, from Dampford sluice to the river, or so much further as may be found necessary, so that its banks may be 30 feet seat, 6 feet at the top, and 6 feet high.

6th. To scour out Tattershall Bane, from the mouth thereof to Dickinson's engine, and repair the banks thereof, so as to be 30 feet seat, 6 feet at the top, and 6 feet high.

7th. To scour out and embank Billinghay Skirth, from the Witham to Billinghay Town, so that its banks may be of the same dimensions as the former; and also to scour out and embank the Skirth, from Billinghay Town to Kyme causeway bridges, so as to be of proportionable dimensions, for draining the low grounds above the said causeway.

8th. To scour out Barling's Eau, from the river to Barling's Abbey, and repair the banks thereof, so as to be 15 feet seat, 5 feet at the top, and 5 feet high; and also to dike out and embank Stainfield Beck proportionable to the former.

9th. To scour out and embank Dun's Dike, from the river Witham to the Carr Dike (or instead thereof to reinstate the Carr Dike, and turn its waters therein), so that its banks may be 15 feet seat, 5 feet at the top, and 5 feet high.

10th. To scour out and embank Nocton Dike and Hare's Head Drain, from the river to the Carr Dike, so that its banks may be 12 feet seat, 4 feet at the top, and 4 feet high.

11th. To scour out and embank Washingborough Beck, from the river to the Carr Dike, of the same dimensions as the last.

12th. To scour out Tupham Dike, Bardney or Tilehouse Beck, Southery Eau, and Stixwold Beck, and embank the same proportionate to the flood-waters they bring down.

N.B. Lodowick's Gowt will be wanted for discharging the river waters during the execution of the work.

And, for the more certain drainage of Wildmore and West Fens, a new cut and sluice, to supply the place of Anthony's Gowt, be made and erected by the side of the said new proposed river, and that the floor thereof be laid as low as the bottom of the said river.

When the works above recommended are put in practice, and have had the necessary time to produce their effects upon the out-fall, we are of opinion, that the surface of the water in the New River will be capable of running at least 4 feet lower,

at ordinary seasons, than at present it can do, and consequently that not only all the lands lying immediately thereupon will be put into a condition of effectual drain age, but also such parishes which at present drain by engines into Holland Fen, or into the several sewers bordering thereupon; and will likewise be of service in affording a more ready discharge of the down-fall waters from the lands lying still further from their out-fall.

THE SCHEME FOR NAVIGATION, VIZ.

1st. To erect a lock with two pair of doors, pointing to the landward, for the purposes of navigation, and one pair of doors pointing to seaward, to keep out the tides.

2d. Upon mature consideration, and comparing the advantages and utility with the increase of expense, we are of opinion that locks are greatly preferable to staunches, though the expense of the former will be considerably more than the latter. We, therefore, propose to erect three locks in proper places, by the side of the mother river, betwixt the sea-sluice and the city of Lincoln, to retain the waters therein for the purposes of navigation in dry seasons (which at the same time will be subservient to the watering of cattle); and one above Sincil Dike in Lincoln, to communicate the navigation of the Witham with the Fossdike: but, that the said locks may not be prejudicial to drainage in wet seasons, the three former are to be so limited in their height, that they shall not retain the waters of the main river any higher than within two feet of the natural surface of the lowest grounds above them; and the weirs or wastes appertaining thereto, shall be composed of flood-gates, which together shall be of the same capacity with the river, in the respective parts where such locks are to be erected, and the latter (proposed to be erected above Sincil Dike) shall be limited to such height, as not to pen the waters higher than the present natural staunch at Brayford Head, and that a waste or weir be erected at the upper mouth of Sincil Dike at G, at the same level with this lock, so that no prejudice may be occasioned thereby to the present state of the Fossdike navigation, or to the low grounds above Lincoln.

3d. For the careful and safe management of the locks, and that the waste gates may be at all times opened upon the approach of any flood, or when the river is overcharged with water, a dwelling house is proposed to be built against each lock, and a watchman to be fixed in each to take care thereof.

4th. To deepen the bed of the river, betwixt staunch and staunch, sufficient for the purpose of navigation, which, at a medium, will be about 13 inches, which done will make 3 feet navigation.

5th. To make proper halingways for men and horses on the banks and forelands of the said river, and that no damage may be done thereby, proper gates, bridges, styles, and fences, be put down betwixt property and property, through which the said halingways may lead.

AN ESTIMATE

Of the Expenses that will probably attend the Execution of the foregoing proposed Works, viz.— the Scheme for Drainage.

	£.	s.	d.
The sea-sluice near Boston to be laid level with the low water mark at Wibberton roads (which is 3 feet 1 inch and nine parts lower than Lodowick's Gowt) with a timber floor, supported by dovetail and bearing piles, braces, and tyes, with a superstructure of brick and stone, with three arches to contain 50 feet neat waterway, the sea and land doors of oak, &c. &c.	4000	0	0
To making the new cut from this sluice, to or near Anthony's Gowt (being 760 roods, at 20 feet to the rood) so as to be 80 feet broad at the top, 50 feet broad at the bottom, and 10 feet deep, at a medium, will contain 32½ floors in a rood, and for the whole length, 24,700 floors, which, as the earth is to be barrowed to the distance of 40 feet from the brink of the river on each side, and laid in bank fashion, and on account of the great depth of the said cut, will cost about 5*s.* per floor (or 400 cubical feet), and comes to	6175	0	0
The inclosed land to be cut through will contain about 6 acres, which, at 30*l.* per acre, comes to	180	0	0
The forelands and cover of the banks will contain about 13½ acres, which, at 15*l.* per acre, is	202	10	0
The commons to be cut through will contain 22 acres, which, at 10*l.* per acre, is	220	0	0
The forelands and cover will be 49½ acres, which, at 5*l.* per acre, is	246	5	0
To taking away the old banks, and cutting across the old river	200	0	0
To erecting a new sluice at Anthony's Gowt, and making the communication cut	600	0	0
To making a new cut across Wildmore Fen, from or near Anthony's Gowt to Chapel Hill (being 1848 roods), 66 feet broad at the top, 50 feet broad at the bottom, and 8 feet deep on an average, will contain 232 floors in a rood, and for the whole length, 42,873·6 floors, which, at 4*s.* per floor, comes to	8574	14	5
The land to be cut through will contain 56 acres of common fen land, which, at 10*l.* per acre, comes to	560	0	0
The forelands and cover of the banks will contain 136 acres, which, at 5*l.* per acre, comes to	680	0	0
To scouring out three miles and a half above Chapel Hill, so as to be 60 feet broad at the top, 40 feet broad at the bottom, and 5½ feet deep below the present bed, will contain 13¾ floors in a rood, and, for the whole length (which is 924 roods), 12,705 floors, which, at 4*s.* per floor, comes to	2541	0	0
To diking out the old river where necessary, and embanking the same from thence to Lincoln, being in length 22½ miles, which, being estimated at 150*l.* per mile, at a medium, comes to	3375	0	0
To erecting a wagon-bridge over the new river, in the road from Langrike Ferry to Horncastle, and two other bridges for communication of the cattle for the use of the commons, and to making good the fencing betwixt Wildmore and West Fens and Holland Fen, about	1000	0	0
To repairing Lodowick's Gowt, and making proper cuts to discharge the water during the work, leaking out water in the reaches, &c.	1400	0	0
To materials of barrows and planks, tressels, gang ladders, engines, and other utensils, &c. and carriage of them to the work	1200	0	0
To scour out and embank Kyme Eau, from Dampford Sluice to the river, and repairing the banks thereof according to the scheme	1000	0	0
To ditto of Tattershall Bane, of the same dimensions as the last, from the Witham to Dickinson's Mill	300	0	0
To ditto of Billinghay Skirths, from the Witham to Billinghay Town, and from thence to Kyme Causeway Bridges, as per scheme	800	0	0
To ditto at Barling's Eau and Stainfield Beck, and repairing the banks thereof to the dimensions mentioned in the scheme	500	0	0
To scouring out and embanking Duns Dike (or the Carr Dike), as directed in the scheme	400	0	0
To ditto of Nocton Dike	275	0	0
To ditto of Washingborough Beck	60	0	0
To ditto of Tupham Dike, Bardney or Tilehouse Beck, Southery Eau, and Stixwold Beck	360	0	0
To unforeseen and incidental contingencies, supervising, and officers to attend this work	3000	0	0
Total for the works of general drainage	37849	9	5

AN ESTIMATE

Of such Works as concern Navigation only, viz.

	£.	s.	d.
To making and erecting the side-lock or penn-sluice, as proposed in the scheme	1200	0	0
To building 3 locks with proper wastes and flood-gates, as per scheme, between Chapel Hill and Lincoln	2000	0	0
To three watch-houses, and purchasing the gound	150	0	0
To erecting the proposed lock in Lincoln above Sincil Dike, as per scheme.....	400	0	0
There will also be a necessity to deepen the bed of the mother river for the purposes of navigation, over and above what is required for draining, upon an average, 18 inches, from Chapel Hill to Lincoln, which is 26½ miles, and will cost about 80*l.* per mile, and comes to	2120	0	0
And for deepening the passage from the lock above Sincil Dike, through the high bridge, into Brayford Meer	200	0	0
To materials of barrows and planks, engines, gang ladders, tressels, &c. for this work..	500	0	0
To unforeseen contingencies and supervising the works	800	0	0
Total for navigation	7370	0	0

Sleaford, November 23, 1761.

JOHN GRUNDY.
LANGLEY EDWARDS.
J. SMEATON.

RIVER CHELMER NAVIGATION.

The Report of John Smeaton, *Engineer, concerning the practicability of making the River Chelmer navigable from Malden to Chelmsford, in the County of Essex, from a view thereof taken the 28th and 29th of May,* 1762*; from whence it appears as follows:*

1st. That the river above Chelmsford bridge, which runs alongside the town for about a furlong, is sufficiently deep and capacious for navigation, and so continues below the said bridge, till within about half a furlong of Mouseholm Mill, where it seems too shallow. This tract of the river appears convenient for wharfs and landing-places; but in case it should be thought proper to carry the navigation above bridge, one of the arches must be taken down and rebuilt, none of them being of sufficient capacity for the craft to pass. There is also ample convenience for making wharfs, either by pursuing the Chelmer, or by cuts through the level meadows on the north-east side of the town.

2d. Mouseholm Mill may be passed by a cut and a lock on either side, but I apprehend with most convenience on the north side; the cut to fall into the river about half a furlong below the mill, where the river makes a remarkable elbow to the north. This will avoid the shoals below the mill; the water from the waste gates of the Chelmer near the town to fall into this new cut below the lock, and be conveyed thereby to the point already remarked.

3d. From the point above remarked, the river continues good till about a half a furlong above Harrington's Mill, where there are further obstructions, which continue below that mill very near to Sanford Mill, and below Sanford Mill the river is remarkably narrow, winding, and obstructed with weeds and beds of sand and gravel for above a mile, and grows very little better till opposite Captain Honeden's house; after that it is still winding, and much obstructed with weeds, &c. till a quarter of a mile above Boreham Mill; but below the paper mill the river is again shallow,

narrow, and obstructed, so as to be in no respect fit for navigation, till a little below Langford Church (which stands within fifteen yards of the river); from hence the river is spacious and good down to How Mill. The river at How Mill, and from half a furlong above, verges so close to the high land, that no cut is practicable there on the south side of the river; but on the north side there is an extent of flat meadows.

4th. Now, considering the great difficulties and obstructions that occur in the river, between Harrington's Mill and Langford Church, a space near upon 7 miles, and that no part worthy of consideration appears at present in a navigable state, except the space aforesaid, about three quarters of a mile between Boreham Bridges and Paper-mill; and, considering that the extra charges in getting into and out of the river, in order to occupy this space, would nearly be equivalent to the expense of continuing a cut by the same, I am, therefore, of opinion, that the most cheap, as well as effectual method of making a navigation, would be to desert the river at an elbow about half a furlong above Harrington's Mill, veering away towards the south-east till it meets the high ground, and then pursuing the skirts of the rising ground, that is, as much as possible the confines between the upland and the meadows, which is in general land of the least value. A cut may be continued with very little interruption on the south side of the river, from the point aforesaid, just above Harrington's Mill, to another point a little below Langford Church, making locks at proper places so as to suit the declivity of the ground.

5th. The course of the river below How Mill becomes again narrow, shallow, winding, and obstructed with weeds for a space of 2 miles, and is not sufficient for navigation till about half a mile above Bealy Mill, and from thence it holds good to Bealy Mill.

6th. The spring tides flow about 5 feet at the tail of Bealy Mill, so that lighters come up thither at those tides to take away their goods. At common neap tides there is little or no flux here. The distance from thence to Malden, by the course of the river, is somewhat less than a mile; and the water runs upon a gentle declivity at low water from those mills to Malden Bridge. The common spring tides flow 8 feet or upwards, at Malden Bridge, and the neap tides about 3 feet; but the neap tides sometimes fall so short even here as not to rise above 1 foot. These observations concerning the tides were taken partly from my own observations of the tide marks, and partly from the best information I could procure upon the place.

7th. Considering the natural course of the river from How Mill to Malden Bridge, as aforesaid, I am of opinion, that the cheapest way to make the most perfect navigation the circumstance will admit of, is to take a cut out of How Mill-pond, with a lock thereupon, leaving How Mill to the south, and either keeping wholly to the north of the river, or otherwise intersecting the river twice within three quarters of a mile below How Mill, to pass by Bealy Mill without coming into its pond at all, leaving that mill on the south, and keeping down the meadows to drop into the river a little above Malden Bridge, on the north side of the river.

'Tis true, that the cut might ultimately drop into the river just below Bealy Mill, which would save about three quarters of a mile of cut; but as there is, according to the above information, at a medium near 3 feet more tide at Malden Bridge than at Bealy Mill, the difference would be, that in one case a communication between Chelmsford and Malden would seldom be interrupted, and in the other case never open but at spring tides.

Upon the whole, I am opinion, that though there is a possibility to make the

river Chelmer navigable by its natural course, yet there is so small a proportion thereof that is at present adapted to navigation, that it will prove the least expense, and by far the most eligible method, to perform the same chiefly by canals in the manner above specified, which canals being supplied with sufficient bridges for the public roads, carriage and other bridges for communication between private properties, under-ground tunnels and passages for brooks and water-courses, and back drains for carrying off any soakage that may happen where the water is confined by banks above soil; I say, things being thus provided for, the private properties of land will be no otherwise affected, than by so much diminution as shall be necessary for the works themselves. And having made observations on the quantity of water current in the Chelmer at the time of this view, I am of opinion, that one sixtieth part thereof will be sufficient for passing one vessel per day, and, consequently, that the mills will not be sensibly affected by loss of water, at the same time they are most of them being capable of being improved to near double their present produce. Lastly, having considered the above particulars, and made an estimate of the expense, so far as I can judge without a more particular and accurate survey of the whole, supposing the length not to exceed 13 miles of new canal, the whole fall not exceeding 67 feet, and the value of the land not exceeding 60*l.* per acre, 3 feet navigable water, and the whole performed so as not to require above 1*l.* per cent per annum, of the first expense to keep the same in repair for ever, may be done for 16,697*l.*

Austhorpe, 21 *June*, 1762. J. SMEATON.

POTTERICK CARR.

The Report of John Smeaton, *Engineer, concerning the Drainage of Potterick Carr, near Doncaster, in the County of York, from a View and Levels taken in July* 1762.

Potterick Carr is a fenny piece of ground, containing, as appears by an old survey of Saxton's, about 2300 acres: in its present state no brook or spring of any account discharges itself thereupon, so that it is affected only by the down-fall waters which fall immediately thereon, and from the higher grounds which border upon the same. These down-fall waters, however, on account of the natural flatness of its surface, the imperfection of its present drains, and the want of a sufficient out-fall to discharge them, generally overflow the whole, or greatest part thereof, during the winter season; which waters are partly discharged by the drains, and partly evaporated by the sun, so as in dry summers to be tolerably dry, as was the case when the present view thereof was taken.

This carr is bounded on the S.E. by the river Torne, which runs considerably above the surface of the carr, but is banked off so as seldom to overflow the same; the whole drainage of the carr is therefore performed by a separate drain, called Stecking Dyke, which falls into the Torne, near Rosington Bridge, about half a mile below the lowest point of the carr.

On the opposite side of the river Torne, extending the whole space that river borders upon Potterick Carr, and somewhat higher, is Holmes Carr, consisting of some hundred acres, which are also banked off from the Torne, so as to be seldom overflowed thereby. The surface of this carr, for the greatest part, lies also below the surface of the contiguous river, yet somewhat higher than Potterick. This carr is, however, subject to the same inconveniences as Potterick Carr; for in this are

scarcely any drains at all, so that the down-fall water is obliged to find its way over the surface, by a natural declivity, into the river Torne.

Part of the south side of Potterick Carr is bounded by Crookhill bank and drain, which prevents the spring and down-fall waters from Loversal from entering the carr, and which are carried by the said drain into the Torne, at a place called Crookhill Nook.

On the south side of Crookhill bank and drain, and bordering on the river Torne, is a large tract of low land, called Wadworth Carr, the surface whereof lies considerably higher than Potterick Carr; but as the out-fall of its drainage is into the Torne at Crookhill Nook, and the surface of the Torne there being some feet higher than at Rosington Bridge, the drainage of Wadworth Carr is in much the same condition as that of Potterick Carr; and this is said to be the case with a large tract of country bordering upon Wadworth Carr, and extending upwards as far as Tickhill. I therefore propose to consider the drainage of Potterick Carr in a twofold light: first, as it is, or may be, connected with the drainage and improvement of this large tract of country; and, secondly, as to what concerns Potterick Carr alone.

On this account I viewed the whole river Torne, from Rosington Bridge to the out-fall of its waters at Austhorpe Sluice, which is a space that, following the banks thereof, cannot be less than 22 miles; I also pursued the drains leading to Austhorpe Sluice, quite across, by way of the old Dunn, to Thorn Sluice, and from thence into the present river Dunn. I also carried a level from the river Dunn, at the Crimpsal above Doncaster, across the little moor and the high ground, whereon is the road leading from Doncaster to Loversal, at Balby Out-gang gate; thence cross Potterick Carr, by way of the old Eau (a natural lake therein), down to its lowest point, called Toad Holes; thence, by way of Stecking Dyke, to Rosington Bridge, and down to the beginning of the Participants Drain, about 5 miles below Rosington Bridge, and about 300 yards above Gatewood Bridge. I likewise carried a level from the surface of the Torne, at Crookhill Nook, to Rosington Bridge, comparing the same with the surface of Potterick, Wadworth, and Holmes Carrs; and, lastly, a level from the surface of the water of the old Eau, to the top of the lowest grounds of the bridge on Cantley Common, near Doncaster horse-course. From which views and levels I would lay down the following facts and observations.

LEVELS

From the Dunn, at the Crimpsal above Doncaster, to the Participants Drain, near Gatewood Bridge.

	Ft.	In.
1st. Mean surface of the Crimpsal above the water of the Dunn, opposite Newton, 27th July, 1762	8	0
2d. Mean surface of the grounds lying between the Crimpsal and the Little Moor, above the said point of the Dunn's surface	17	0
3d. Mean surface of the Little Moor, above the Dunn	14	0
4th. The causeway, in the road from Doncaster to Loversal, opposite Balby Out-gang gate, above the surface of the Dunn	39	7¼
5th. The mean surface of Potterick Carr, about 100 yards within the border thereof, near the Out-gang gate, above the said surface of the Dunn	5	2⅜
6th. The lowest part of the Carr's surface, near the Division Dyke, on the west side of the dyke, and on Loversal side of the Carr, is nearly level with the surface at the former station, and therefore above the Dunn	5	2⅜
7th. The surface of the water in the old Eau, which may be esteemed the sink of the Carr, above the Dunn's surface	4	4
8th. The surface of the Carr at the Toad Holes, near the old engine, above the surface of the old Eau	1	2
9th. The surface of the river Torne, just below Rosington Bridge, below the old Eau, including a fall at the bridge made by the carriages driving through the water, amounting to 2½ inches.	0	10½

	Ft.	In.
10th. The surface of the river Torne, at the bottom of the straight cut or river, extending about a furlong below Rosington Bridge, below the surface of the old Eau	1	9
11th. The surface of the river Torne, opposite a birch-tree at the side of the meadow on the south side of the river, about 5 furlongs below Rosington Bridge, below the old Eau	4	0
12th. The surface of the river Torne, just above the houses at Oakley Dam, above the old Eau.	4	8¼
13th. The surface of the river Torne at the foot bridge, about 100 yards below the road at Oakley Dam, below the surface of the old Eau	6	0
14th. The surface of the river Torne, at the entry of the Participants Drain, about 5 miles below Rosington Bridge, and about 300 yards above Gatewood Bridge, below the surface of the water in the old Eau	9	6½

CONSEQUENTLY,

15th. The surface of the river Torne, at the birch-tree below Rosington Bridge, is higher than the surface of the Dunn, at the Crimpsal, by	0	4
16th. And the surface of the Torne, at the entry of the Participants Drain, is lower than the surface of the Dunn at the Crimpsal, by	5	2½

LEVELS FROM CROOKHILL NOOK TO ROSINGTON BRIDGE.

17th. The general surface of Wadworth Carr, near Crookhill Nook, above the surface of the Torne, at Crookhill Nook, as was taken 29th July, 1762.	0	9
18th. The mean surface of one of the lowest slades near Crookhill Nook, above the surface of the Torne there	0	1½
19th. The mean surface of the lowest part of Holmes' Carr, opposite Crookhill Nook, below the surface of the Torne there	0	9½
20th. The general surface of Potterick Carr, in the meadows adjoining to Crookhill Nook, below the surface of the Torne there	1	2¼
21st. The height of the bank of the Torne above water, at some of the lowest places on the Holmes' Carr side, near Crookhill Nook, and which the Torne is said very rarely to over-top	0	11
22d. Ditto, on the side of Potterick Carr	0	11¼
23d. Surface of the Torne, at the lowest part of Potterick Carr, called the Toad Holes, below the surface of the Torne at Crookhill Nook	1	8
24th. Surface of the Torne just below Rosington Bridge, including the fall of 2½ inches there, below the surface of the Torne at Crookhill Nook	3	5

CONSEQUENTLY,

25th. From the general surface of the lowest part of Holmes' Carr, near Crookhill Nook, to the surface of the Torne at Rosington Bridge, there is a fall of	2	7½

LEVEL FROM THE OLD EAU TO CANTLEY COMMON.

26th. July 30, 1762, found the rise from the surface of the the water of the old Eau, to the top of Cantley Common, in the lowest part of the ridge between the division dyke and the inclosures next Doncaster.	15	0½

OBSERVATIONS.

27th. From my view of the country, it appears that there is a fall of some feet from low water mark in the river Dunn, near Thorne Sluice, to low water mark in the Trent, at Austhorpe Sluice; and from the above levels, Articles 7th and 14th, it appears, that the surface of the Thorne at the beginning of the Participants Drain, is lower than the Dunn at the Crimpsal, by 5 feet 2½ inches; but as this will scarcely balance the difference at Doncaster Lock, it follows, that the Torne from the entry of the Participants Drain, would have a fall into the river Dunn, at or near Thorne Sluice, at least equal to the sum of the falls of the four locks upon the river Dunn below Doncaster, and, therefore, has at least an equal one into the drain leading to

Austhorpe Sluice, which may probably amount in the whole to 12 or 14 feet, besides the 5 feet 2½ inches above mentioned.

28th. From my view of the country, it further appears, that there is no passage from Potterick Carr to the Dunn, without traversing the ridge of hills extending from Loversal to Hatfield, without going below Hatfield; and since the same point can be attained by following the valley of the Torne, I, therefore, look upon the cutting through the high ground at Cantley Common, in order to come at the same point, as quite out of the question; and to traverse the aforesaid ridge of hills, after passing through those high grounds, will be less eligible than traversing the same at the Outgang gate, and finding the shortest way to the Dunn.

29th. It is generally looked upon, that a capacity of reducing the surface of the water in the drains, 2 feet under the general surface of the lowest lands to be drained thereby, to be effectual for draining purposes, and, therefore, whatever means are capable of producing this effect, will answer the end as well as if they were capable of making a greater reduction, because the surface of the water being too much reduced, with respect to the surface of fen lands, is found to hurt the fertility thereof.

GENERAL SCHEME.

Now, with respect to the general drainage of the country, I take it for granted, that what will drain the lowest slades of Wadworth Carr, near Crookhill Nook, will, by proper leading drains, do for all the lands that lie further up the country; but as there appears to be, from the levels, Articles 17th and 20th, a fall of almost 2 feet from Wadworth Carr into Potterick Carr, which would be sufficient for the drainage of the former, yet, were the down-fall waters of Wadworth Carr and country above let down, so as to communicate with the drains of Potterick Carr, the former would over-ride, and thereby prevent the drainage of the latter, unless both were carried separately to a point where a sufficient declivity might be obtained, so as to carry off both without affecting each other. This purpose may be obtained by cutting new drains separate from the river Torne, so as to deliver their water into the Torne, at the birch-tree below Rosington Bridge, before mentioned (Art. 11), and still more effectually, was the river scoured out, and a bridge built at Oakley Dam, where, from Art. 12 and 13, it appears, that 15¼ inches of level might be obtained in little more than 100 yards, the loss of which is a great detriment to the grounds lying on both sides of the river, between the said birch-tree and Oakley Dam, during which space the river, being deeper than in most other places, would reduce its surface a great part of that quantity lower than at present.

To this scheme will probably be objected, that the down-fall water of a large tract of country being brought down into the Torne at the birch-tree, by more direct passages than heretofore, will be the means of overflowing the meadows below the said point, and also raise the waters in the out-fall drain to a greater height than they would otherwise do. And it must be acknowledged, that something of this would take place, though in so small a degree as scarcely to be sensible at so great a distance from the out-fall: for it must be allowed, that in wet seasons the same quantity of water must be discharged; the only difference is in the time. It must also be allowed, that the water which comes down the drains to the birch-tree, must otherwise have come down the Torne to the same point, and, therefore, the water of the Torne will be eased by that quantity. The time, therefore, can only be affected

by that part which comes down to the drains quicker than it would have done by the Torne; but then, in consequence of this quickness being nearer its out-fall, and coming by a more direct road, it will generally happen that the bulk of the down-fall coming by the drains will be gone off, before the bulk of the land waters that come from other places at a great distance by the meandering course of the Torne are arrived; and consequently, in such cases, the rapidity of the waters coming down will, upon the whole, be rather abated than increased.

But if this reasoning, however true and explicit, should not prove satisfactory to those who are to get nothing by perceiving the truth thereof, I see no way of steering clear of the objection, but by bringing a new drain from the river Dunn, entirely independent of the river Torne; and I do not find any better way of doing this, than by beginning at some proper point upon the river Dunn, below Stainford Lock, and above Thorne Sluice, from thence traversing the level moors, and leaving Gatewood to the north, to approach near the Torne at Gatewood Bridge, and leaving this bridge, as well as the whole river Torne, on the south, to follow the low meadows quite away to Potterick Carr, and through the same up Wadworth Carr, &c.

In this case, it would be necessary to erect a small sluice at the out-fall of this drain into the Dunn. This method would effectually drain, not only all the country above Rosington Bridge, but be of great service to the lands through which it passed below, and might be executed at a moderate expense; for though the distance is considerable, yet there is so great a sufficiency of level, as appears by Art. 27, that a small drain would answer the end. This drain would be somewhat shortened, and the out-fall sluice avoided, in case the proposed scheme for making a navigable communication between the Dunn near Thorne Sluice, and the Trent near Authorpe Sluice, should take place; in which case, the two schemes would be of mutual assistance to each other. Yet as the execution of this scheme of drainage, in either method, however practicable in nature and art, would necessarily pass through and sever many properties, how far it may be practicable respecting men's interests and opinions, I cannot take upon me to say.

SCHEME FOR POTTERICK CARR.

I come now to consider what may be done towards the drainage of Potterick Carr, independent of the rest of the country, by such methods as lie within a narrow compass, and as it were within the districts of the corporation of Doncaster, and proprietor of Loversal. And here two methods offer themselves; one by a subterraneous passage from Potterick Carr to the river Dunn, by way of the Crimpsal; the other by way of Stecking Dyke, which appears to be the ancient out-fall drain for Potterick Carr into the Torne, at or near Rosington Bridge.

1st. With respect to a passage from Potterick Carr to the Dunn above Doncaster, it appears, Art. 7, that when the levels were taken, there was a fall of 4 feet 4 inches from the surface of the old Eau to the surface of the river Dunn, the distance being about 2 miles. It appears, also, Articles 5, 6, 7, and 8, that the surface of the old Eau at that time was about 10 inches below the general surface of the Carr; therefore a capacity of running off the surface of the old Eau 14 inches lower than at present, would, with proper internal drains, complete the drainage of this Carr, and still there would remain 3 feet 2 inches fall from the water of the old Eau to the surface of the Dunn; but as the verge of the Carr, near Balby Out-gang gate, is about

a mile nearer to the Dunn, to which all the water of the Carr would be brought, in open drains, with very little loss of level, there would be 3 feet descent for the subterraneous passage, which from this point would not, in the nearest direction, be above a mile, which is so large an allowance of descent, that, supposing a clean bottom carried upon a dead level from the surface of the Dunn, a drain of 3 feet wide would sufficiently discharge the water.

The disadvantages attending this scheme would be, that whenever the surface of the Dunn should, in rainy seasons, be kept higher than 3 feet above its common pitch, which I suppose it sometimes is for weeks together, that then there could be no drainage at all; but on the contrary, without the help of a subterraneous sluice, the water of the Dunn would run into the Carr.

This inconvenience would, in great measure, be obviated by carrying the drain so low as to fall into the river Dunn, between the water-engine and the bridge at Doncaster; for this would gain an addition of 5 or 6 feet of level. And though, in the height of great floods, I suppose there is not a great deal of difference of the Dunn's surface above and below the engine-dam, yet I suppose that the water rarely continues there for any length of time together, so as to be 3 feet higher in the engine-tail than the ordinary surface of the Dunn, at the Crimpsal, opposite Newton. So that the drainage, being stopped but for a little time together, would be sufficiently performed by intervals: but then, as this will create about three quarters of a mile addition of drain, and thereby add to the tediousness and expense of an otherwise tedious and expensive job, it will still remain a question, how far this method of drainage may be eligible, especially when 'tis considered, that, should a running sand be met with in this passage, it might prove an insurmountable difficulty, and the work be obliged to be deserted, after great expenses incurred thereupon.

2d. With respect to a drainage into the Torne, if Stecking Dyke was carried down on the north side of the river, and dropped into the Torne, at the birch-tree, below Rosington Bridge, this scheme would be undeniably the best of any; for to this place, from the old Eau, there is near upon the same fall as into the Dunn, at the Crimpsal, opposite Newton, with an opportunity of making a drain of any given capacity that may be required; and as it appears, from Art. 21 and 22, that the waters of the Torne don't rise in time of floods above a foot perpendicular, the flood water of the Torne can never over-ride those of the drain: and whatever force may be supposed to remain in the objection to the delivering the down-fall water of the whole country into the Torne at this point, it will entirely vanish when applied to Potterick Carr alone; for being of so much less extent, and nearer to its out-fall, and having so good a declivity, its water will be certainly discharged before those from the different parts of the country are come down; and in long-continued rains it is plain that when the Carr is once overflowed to a certain height (as is the case at the close of winter, when surface waters are most annoying) that the present discharge of water from the Carr, at those times, will be just equivalent to its discharge of water in the same time when in a state of drainage.

But I will now suppose the worst, and take it for granted that nothing can be done but by such lawful means as may be put in practice within the grounds of Doncaster and Loversal.

It appears by the levels, Art. 9 and 10, that from the surface of the old Eau to the lower side of Rosington Bridge is a fall of $10\frac{1}{2}$ inches, and from thence to the lowest part of the straight cut, extending about a furlong below the bridge, is $10\frac{1}{2}$ inches more, in the whole 1 foot 9 inches; but, as a reduction of the surface of the old Eau of 14 inches below its then state has been shewn sufficient for drainage,

there will still remain 7 inches fall from the old Eau to the point last mentioned, which is amply sufficient, as the distance does not exceed a mile and a half.

Now, the straight cut aforesaid, below Rosington Bridge (which passes through the bounds of the corporation of Doncaster, or Mr. Dixon, of Loversal), plainly appears to have been made with a view to the drainage of Potterick Carr: for by cutting off the loops of the old river, and making a more free passage for the Torne, the surface of the water would naturally be reduced at the tail of Stecking Dyke, and consequently afford a better fall from the Carr; and even by this construction, had the whole been done in a proper method, and with proper dimensions, a drainage might have been accomplished, and with good management preserved to this day: but at present I would rather advise to let the Torne continue its present course, and to cut a new drain on the north side thereof, through the said lands, from the lowest point of the said straight cut, up to Stecking Dyke; and, either by scouring out and enlarging Stecking Dyke, or by cutting a new drain in lieu thereof, this, with proper internal drains within the Carr, will reduce the water 2 feet 7 inches within the general surface of the lowest lands in dry seasons, unless held up to a greater height for the use of cattle.

It appears from Art. 21 and 22, that the greatest rise of the Torne in time of floods at Crookhill Nook does not exceed 1 foot perpendicular; but there is reason to suppose it may be somewhat more at the point before mentioned, possibly 15 inches, and therefore it will be necessary to place a sluice or doors at the tail of the drain, to shut against the water of the Torne at such times, and prevent their reflowing into the Carr: yet, if the drains are made of sufficient depth and capacity to run off the waters of the Carr to the dead level of 2 feet 7 inches below soil, those drains will be sufficient to hold water, so as to drain by intervals without overflowing the surface of the Carr.

It is possible the same objection may still be urged against this scheme as against the former, of going down to the birch-tree, viz. that of bringing down the waters more suddenly upon the lands below: but for this, in the present case, there is most evidently not the least foundation; for, since it will be necessary to maintain a pair of doors to shut against the Torne in time of floods, it is plain the drainage water can make no addition while its doors are shut; and as they must escape when the bulk of the floods in the Torne are spent, it must contribute to the carrying off the whole more equally than at present. And, since this scheme can be executed within the grounds of the parties concerned, and cannot possibly, even in appearance, prejudice those of any other, I apprehend there can be no doubt of the legality thereof; and as this scheme can be executed at much less expense than any other, for my own part, I think it merits trial.

I hope what has been said will be sufficient to let the proprietors of Potterick Carr see clearly the nature of this business, and to determine them in the choice of a method: when that is done, I shall be ready to make what further observations may be necessary, in order to lay down the particular plan and dimensions, and form an estimate thereupon.

With respect to Holmes Carr, it will readily occur, from what has been said, that there cannot be the least difficulty: for, since there is 2 feet 7½ inches fall from the lowest parts opposite Crookhill Nook to Rosington Bridge, that nothing more is necessary than to put the banks against the Torne into proper repair, and to make proper drains to carry the down-fall water into the Torne at, or immediately below, Rosington Bridge, on the south side of the river, with proper gates to shut against the floods, as before mentioned; or otherwise, by an under-ground tunnel or fox, to

communicate its waters to the drain proposed for Potterick Carr, which, in this case, must be somewhat enlarged on this account.

Austhorpe, September, 1762. J. SMEATON.

ESTIMATE

For Draining Potterick Carr, Holmes Carr, and Wadsworth Carr, by a Passage from Potterick Carr, by Balby Out-gang Gate and Spansyke, to the River Dunn, below the Engine at Doncaster; the Tail of the Drain to be laid 8 feet below the mean surface of the Carr, and to rise 1 foot to the Out-gang Gate.

	£.	s.	d.
To digging out the tail-drain for an arch, length 5 chains, in order to get round the engine into Mr. Copley's meadow, adjoining to Crimpsal; mean depth 10 feet bottom, width 6 feet, and to batter half a foot in a foot a perpendicular, containing 1760 cube yards, at 3½*d.* per yard	25	13	4
To walling the sides 4½ feet high, which if done with Extrop stone, or brick length wall, may be done for 14*s.* per rood, and for one chain there will be 9 roods 3 yards	6	12	0
The floor being set with Extrop stone, 9 inches deep without mortar, if done for 1*s.* 3*d.* per yard, each chain contains, at 5 feet wide, 37 yards	2	6	3
To arching the same with brick, at 5 feet span, so as to rise 18 inches, the exterior curve will contain 7½ feet breadth, and in 1 chain at brick length thick, 7 roods 6 yards	5	10	0
Value of one chain arching	14	8	3
Which, in round numbers, we will call	14	10	0
To 5 chains of arching, at 14*l.* 10*s.* per chain	72	10	0
To ramming behind the walls, fitting-in and righting-up earth, at 1*s.* per yard	3	13	4
To temporary damages, at 1*d.* per yard, upon the surface opened, containing 660 yards	2	15	0
To extra work, securing the apron, making a front wall next the river, and hanging a sluice-door to prevent the water of the river Dunn from reverting into the Carr in time of floods	20	0	0
From the aforesaid drain for 5 chains, through Mr. Copley's close, and from thence 24 chains through the Crimpsal, total length 29 chains, may be an open drain, which, at 9 feet mean depth, 6 feet bottom, and 4 feet batter per yard perpendicular, turns out 11,494 yards, at 3*d.*	143	11	0
The mean width of the cut at top will be 30 feet, which, in 29 chains, produces 6386 yards, equal to 1 acre, 1 rood, 11 perches; and each bank will nearly occupy the same space: but this is supposed to be left of half value; so that, for the two banks we reckon 1 acre, 1 rood, 11 perches, and in the whole 2 acres, 2 roods, and 22 perches, which, if valued at 60*l.* per acre, comes to	158	5	0
From Crimpsal, up Spansyke Closes, 26,26 chains, mean depth 12 feet, with 6 feet bottom, and 4 to 3 slopes, will turn out 16,995½ yards, at 3*d*	211	18	10½
The mean width at top will be 38 feet, which, at 26,26 chains long, makes 7315 yards, equal to 1 acre, 2 roods, 2 perches, which, doubled for the cover, makes 3 acres and 4 perches, which if valued at 50*l.*	155	0	0
A bridge across at the Extrop Road	30	0	0
From the top of Spansyke Closes to the entry upon of the little moor, is 18½ chains, the mean depth 16 feet. The digging out a 6 feet bottom, with half a foot batter, in a foot high, will turn out 10,664 cube yards, which, at 4*d.* comes to	177	14	8
To arching 18,5 chains, at 14*l.* 10*s.*	268	5	0
To ramming, filling, and righting the ground, at ½*d.* per cubic yard	22	4	4
To temporary damages, at 1*d.* per yard superficial of the ground opened, 3138, comes to	13	1	6
From the entry of the little moor across the same to the base of the hill, about one chain, within the Green-Lane, is 23 chains, mean depth, 17 feet; the digging out a 6 feet bottom, at ½ a foot batter in 1 foot rise, will turn out 13,859 yards, which, at 4*d.* a yard, comes to	230	19	8
Carried over £.	1535	11	8½

	£.	s.	d.
Brought over	1535	11	8½
To 23 chains of arching, at 14*l.* 10*s.*	333	5	0
To filling in 13,859 yards, at ½*d.*	28	17	5½
From the base of the hill, one chain upon the same being at a medium 20 feet deep, with bottom and slopes as before, containing 782 cube yards, at 5*d.*	16	5	10
To arching ditto, as before	14	10	0
To filling ditto, 782 cube yards, at ½*d.*	1	12	7
To open-casting on the side of the hill next the Carr one chain; mean depth, 12 feet; with a 6 feet bottom, and slopes as before	15	0	0
To open-casting, arching, and filling one chain more; mean depth, 16 feet	27	0	0
To open-casting, arching, and filling one chain; mean depth, 20 feet; as on the other side of the hill	33	0	0
Charge of the out-fall drain, exclusive of the hill	2005	2	7
The length of the under-ground passage through the hill, which cannot be conveniently open cast, is 13 chains, that is, 286 yards; but as the quality of the matter is not known at the depth it is to pass, it is impossible to estimate the charge of getting through it; if it turns out any kind of matter that will stand unsupported till arched a fathom at a time, it may be done for about 4*s.* per yard, pitting included; but as it may be attended with some extra trouble, if we allow 2*l.* 10*s.* per yard, then, 286 yards at 2*l.* 10*s.* come to	715	0	0
To extra work in fixing a drawgate at the entry of the subterraneous passage, in order to take off the water, to repair or inspect any thing within, and which will also serve for holding in water for the cattle in dry seasons	20	0	0
Estimated expense of the out-fall drains	2740	2	7

N. B. The whole length is 119 chains, or 1½ mile wanting one chain.

MOTHER DRAINS, BARRIER BANK, &c. WITHIN THE CARRS.

To digging a mother drain from the entry of the subterraneous passage to the old Eau, being in length 1¾ mile, to be 21 feet top, 9 feet bottom, and, at a medium, 6 feet deep; containing 30,800 cube yards, at 2*d.*	256	13	4
To continuing the said drain from the old Eau to Crookhill Nook, in order to receive the water by foxes, from Holmes Carr under the Torne, and from Wadworth Carr under Catherine Well Water, being in length 1¼ mile, to be 19 feet top, 9 feet bottom, and, at a medium, 5 feet deep; containing 17,111 yards, at 2*d.*	142	11	2
To the making a fox, about 2 yards wide and 1 yard high, for taking the water from Holmes Carr under the river Torne	60	0	0
To a ditto, about a yard square, from Wadworth Carr, with a shuttle for regulating the water, that it does not come down faster than the mother drains in Potterick Carr will vent it	55	0	0
To cutting a back drain behind the bank of the Torne in Potterick Carr, and thereby strengthening the bank against the river, being in length about 1½ mile, to be 3 yards mean width, and a yard deep, cutting and banking at 2*d.* per yard	66	0	0
To ditto behind Crookhill Bank, 1 mile (or so far as may be found necessary) of the same dimensions	44	0	0
To cutting a mother drain within Holmes Carr, parallel with the general course of the river, avoiding the loops, and therewith forming a bank against the same, leaving 20 feet foreland in the nearest places; the length supposed 2½ miles (more or less as may be necessary), to be 5 yards top, 2 yards bottom, and, at a medium, 4½ feet deep, containing yards, at 2*d.*	192	10	0
To cutting a mother drain, in like manner, in Wadworth Carr, disposing the earth bank fashion, as before-mentioned. The drain to be 4½ yards top, 1½ bottom, and, at a medium, to 1½ deep, supposing the length 1½ mile (more or less, as may be necessary), will contain 11,880 yards, at 2*d.*	99	0	0
To strengthening Catherine Well Water Bank against Wadworth Carr by a back drain, 3 yards wide and 1 yard deep, supposing the same 1 mile (more or less, as may be required)	44	0	0
Carried over.	£.959	14	6

	£.	s.	d.
Brought over	959	14	6
To banking on both sides the drain by the side of the road over Wadworth Carr, which brings down the water of some springs, and also for making catch-water drains to conduct the upland water into the river, supposing the whole to be 2½ miles (more or less, as may be wanted), 3 yards wide and 1 deep	110	0	0
Estimated charge of the internal works	1069	14	6

GENERAL ACCOUNT.

		£.	s.	d.
The out-fall drains	†	2740	2	7
The internal works		1069	14	6
Contigent expenses upon the whole, the perforation of the hill expected		400	0	0
Total	*	4209	17	1

N.B. The sum marked thus † was in the original 2732*l.* 6*s.* 0*d.* and the total marked thus * was 4202*l.* 0*s.* 6*d.*

OBSERVATIONS.

1st. In case a red sand rock should be found in the hill, at a level of the drain that will stand of itself, it may be done for 1*l.* 5*s.* a yard; but in case it should be a soft clay, or running sand, it may cost 10*l.* a yard.

2d. In case of such a sand or clay, it will be advisable to sink for a firmer matter below, in which case, the water may be carried under the hill in manner of an inverted syphon.

3d. If a red sand rock should lay in a right line between the engine and Carr, as the distance is only 65 chains, it might be cut for about 1828*l.*

4th. If such a rock should be found between the top of Spansyke Closes, in a right line to the Carr, the length being 33 chains, the whole expense of the out-fall drain will be done for 1751*l.* But

5th. If this last space should be the same matter as supposed in the estimate for Outgang gate, the out-fall drain would be done this way for 2659*l.* but the hazard greater.

6th. As much depends upon the quality of the matter, it would be advisable to bring this affair to a certainty, by sinking or boring.

7th. The charge of carrying the drain from the top of Spansyke Closes across the little moor to the entrance of the hill, will be somewhat cheaper by an open drain than by arching; but, as the cut and banks would occupy between 50 and 60 yards broad, would be less eligible to the land owners, and the drain more liable to obstruction, by matter tumbling from such very high banks.

N.B. The bottom for the arching parts is supposed to be dug no more than six feet wide, though the drain within the walls is purposed to be of five feet, because the foot of the slopes may be cut down perpendicular half a foot on a side, when the masons are ready to put in the walls.

Doncaster, March 23, 1764. J. SMEATON.

TO MR. SHEPPARD, CONCERNING POTTERICK CARR.

SIR,

In answer to your request, my report is as follows:

That in the dry season in July 1762, I found the waters of the old Eau in Potterick Carr nearly ten inches below the mean surface of the land in the Carr, which, in the points I tried it, was nearly upon a level, which are specified in my report, and to which I refer; that from the surface of the water in the old Eau, to the surface of the river Torne, just below Rosington Bridge, I found a fall of 10½ inches, and from thence to the bottom of the straight cut, or river below Rosington Bridge, 10½ inches more, making together 1 foot 9 inches below the surface of the old Eau, as it and the river then were; but it is to be remarked, that the surface of the water in the river just below Rosington Bridge was 13 inches below the first apparent joint of the arch on the south-east angle thereof; whereas, when I viewed it on the 20th of May last, it was nearly 6 inches above the same.

I also find, from my notes taken in 1762, that from the bottom of the straight river aforesaid, to the birch-tree mentioned in my report, I made two stations, amounting together to 2 feet 3 inches fall; the first below being 11¼ inches, and the second, 15¾ inches; but how far the first station of 11 inches extended below the straight cut, I do not now remember, having no remark thereupon, the extent of the corporation's estate on the south side of the river not being at that time distinctly pointed out to me; but I have reason to believe, that at least 6 inches of the 11 would fall within the corporation's estate; so that hence I infer, that from the surface of the old Eau, to the surface of the river Torne, at the bottom of the corporation's estate, as the old Eau and river then were, was at least 2 feet 3 inches, and, consequently, below the mean surface in the Carr, 3 feet 1 inch, and which I don't doubt but will appear the same, whenever the obstructions, which I apprehend to be since formed in the river below Rosington Bridge, are removed, so as to suffer the surface of the water to subside to the same point upon the bridge, as it was even with in 1762; and consequently, that with the fall above mentioned, the Carr may be effectually drained, as 2 feet below the surface is generally esteemed by the most experienced engineers a complete drainage.

For this purpose, I apprehend it will be convenient to cut a new passage for the river Torne from some proper place at or above Crookhill Nook, and skirting the high ground on Rosington side, as much as consistent with a short course to bring the same down to Rosington bridge, and building a new bridge for the new river on the south side of the present bridge, to carry down the new cut through the corporation's estate on the south side of the present river, and to drop the same into the Torne at the lowest point of the said estate. This new river, being properly embanked, will defend the lower grounds of Potterick Carr from the floods of the Torne, and, by proper drains and tunnels, will drain Holmes Carr, and the higher grounds to the westward of the same, without interfering with that of Potterick Carr.

The dimensions of this new river ought to be at least 20 feet bottom, with proper batters, or slopes, of at least 1 to 1. The bottom, at the tail of the new river, to be at least 2 feet below the surface of the Torne there, as it was in July 1762, that is, 4 feet 6 inches nearly below the said joint in the arch, and to rise upon a plane regularly inclined, so as to be at least 4 feet below the surface of the adjacent carrs, where it joins the old river at or above Crookhill Nook.

For the drainage of Potterick Carr, I would recommend to cut a new drain between the proposed new river and the old one, beginning at the old river just

above the tail of the new one, and joining the straight river as soon as possible, to widen and deepen the same in its present course, so as to pass under the present Rosington Bridge; and from thence keeping on the north side of the old river above Rosington Bridge, to join Stecking Dyke, widening and deeping the same nearly according to its present course, to the place where the engine stood, from thence keeping a straight course, or as nearly so as the convenience of properties will allow, through the middle of the Carr to the north end thereof.

This drain I would recommend to be at least 18 feet wide at the bottom, with slopes of at least 1 to 1, and to be at least 5 feet 6 inches below the said joint in the arch, the bottom to be carried upon a dead level, and of an equal width as far into the Carr as till it is opposite the old Eau, from thence to grow gradually narrower and shallower, so as to be 4 feet deep and 5 feet bottom at the head; this, with proper cross drains, will reduce the water in the Carr to very near the same level as the river at the out-fall of the drain. I would further advise that a sluice with doors, pointing toward the Torne, be erected at the tail of the drain, to prevent the water of the Torne in great rains from over-riding those of the Carr, and thereby reverting into the Carr, and also a stop-sluice with draw-doors upon the tail of the proposed new river, by shutting which, at proper times, the proposed drain will run at times when it otherwise would not; a sluice-keeper being appointed to take care of the drawing and shutting the same, so as to prevent their running or penning improperly, on account of the lands above and below.

A catch-water drain round the skirt of the Carr will be of great use in conveying the water from the uplands into the new river, without entering the Carr; but, as the country is not very extensive which at present throws down water upon the Carr, this expedient need not be put in practice till experience shews it to be wanted.

The above reasoning principally depends upon two points, which I would recommend to the commissioners to satisfy themselves upon, viz. whether obstructions in the river below the corporation's estate can or cannot be removed, so as to run off the the water to the same depth as I found it in my survey in July 1762; and, secondly, whether, in that state of the river, there is or is not the quantity of fall specified, or near upon.

I am, SIR,

Your most humble Servant,

JOHN SMEATON.

P.S. The joint of the arch being a little inclined, I took my measure from the lowest side next the water.

THE REPORT

Of JOHN SMEATON *and* JOHN GRUNDY, *Engineers, concerning the practicability of improving the Fossdyke Navigation, and Draining the Land lying thereupon; from a View and Levels taken in August* 1762.

The Fossdyke is an artificial cut or canal, which joins the Trent and Witham together, by a navigable communication, extending from the Trent, near Torksey, to Brayford Meer, near the city of Lincoln, being in length near upon eleven miles. The river Witham, which has its origin near Post Witham, in Lincolnshire, after

pursuing a course of about 40 miles, falls into Brayford Meer, which, being a natural reservoir of several acres in surface, and having an open communication with the Fossdyke, as also with two other still more extensive lakes, or natural reservoirs, called Swan Pool and Cuckoo Pool, their surfaces being common, and nearly at rest, will, consequently, be nearly upon the same level, and rise and fall together.

The end of the Fossdyke next the Trent is shut by a lock, having gates pointing both ways, which, of consequence, equally prevent the waters of Fossdyke from flowing out into the Trent, or the waters of the Trent from flowing into the Fossdyke, according as each surface happens to be lower or higher than the other. The waters of Brayford Meer, and, consequently, of the Fossdyke, are prevented from running off below a certain height, by a shoal in the river Witham, between Brayford Meer and Lincoln High Bridge, called Brayford Head, or the Natural Stanch. There are also three other passages for the water of the Witham, before it falls into Brayford Meer, which are called Sincil Dyke, and the two Gowt Bridge Drains; the two latter join the former, and fall into the river Witham below the said shoal of Brayford Head, a little above Stamp End, which is the lowest point of the city of Lincoln; from hence the waters of the Witham make their way through the fens towards Boston; but as the highest part of the bottom of Sincil Dyke and Gowt Bridge Drains is several inches higher than the top of the shoal of Brayford Head, those serve only as slaker drains, to ease off the passage of the water in time of floods; but Brayford Head is considered as the gage, weir, stanch, or tumbling bay, by which the water of Brayford Meer is kept up to a certain height, and discharged when above the same.

Now, there being a great quantity of low grounds, which have their drainage into Brayford Meer and into the Fossdyke, and their communications, which cannot, in the present state of Brayford Meer, be effectually drained, for want of a sufficient fall from the lowest parts of their surface, it is, therefore, desirable to the proprietors of those lands that Brayford Head should be removed, or at least so far lowered, that the water of Brayford Meer, and, consequently, the Fossdyke water, being so much sunk below its present gage surface, as to afford a sufficient declivity from the surface of the lands thereinto.

On the other hand, the Fossdyke navigation being at present deficient in depth of water, it is equally desirable to the proprietors thereof that Brayford Head should be raised.

To reconcile those opposite interests, and give to each party what they desire, without injury to the other, is the point at present before us.

In the first place, it is very obvious that, was Brayford Head lowered a certain number of inches, and the bottom of the Fossdyke lowered as much, that the lands would be bettered, and the Fossdyke navigation would be in the same state as now; and if beyond that, the bottom of the Fossdyke was lowered as many inches more as it is at present deficient, then the navigation would be bettered also, and both sides would get what they want.

In order to examine the merits of this proposition, we sounded the depths of the Fossdyke, and examined the qualities of its bottom, measured the width, and took the height of the banks, in a variety of places, between one end and the other, and made what other observations we could, in order to inform ourselves with the circumstances that would be likely to occur in the execution of such a project: in consequence whereof, we found that (some few places excepted) the bottom was either a rotten peat earth, or else a running sand; and from the efforts that have already been made from time to time, in order to clear the bottom, and by the

wharfing up the sides with piles, plank, and stone, as well as from the nature of the soil itself, it appears to us to be very difficult and expensive to preserve the present depth of water upon its present width; and though we are of opinion that the deepening thereof in the requisite degree to answer the purposes aforesaid, is in nature possible, yet, as it appears to us that this deepening cannot be effected without moving one of the banks, in order to widen the same, and give a proper foreland thereto, and that in a very considerable degree for the greatest part of the length, it will, in consequence, not only turn out a very expensive project, which, by an estimate we have made thereof, amounts to upwards of 6000*l.* but be the occasion of much loss of time and profit to the proprietors of the navigation while the work is executing; and, as it appears to us, will not be so eligible even to the landowners themselves, as the following scheme of drainage would be; for it is most manifest, that no grounds which drain into Brayford Meer, Fossdyke, or any of the pools or communications that lie upon the same level therewith, can receive any greater prejudice by the present height of water in the Fossdyke than heretofore, unless it can be proved that Brayford Head is now higher than it was, for if it is not, the expense of such deepening must, in a great measure, fall upon the proprietors of lands, for whose sake principally it is done, it being no matter which concerns the proprietors of land, how deep the bottom of Fossdyke is below the gage surface of its water, but only whether this gage surface is higher now than it was; if not, and the lessors and lessee of the Fossdyke are disposed to be contented with its present depth, rather than be at the charge of deepening, the deepening, with all its consequences, will then become the business of the land owners only, except what it shall be reasonable for the Fossdyke proprietors to contribute, for the advantage of a greater depth than at present, after all losses and damages that they shall sustain thereby are made good.

Whether Brayford Head is higher now than formerly, is not for us positively to determine; and though it is possible some accession of matter might have come to Brayford Head from various causes and accidents, yet as the shoal is not composed of fixed matter, it may, notwithstanding, have been upon the whole in a state of diminution, rather than increase, since the increase of traffic, by the passing of boats and carriages upon and over it.

Having viewed and taken the levels of various points of the surface of those lands which drain into Fossdyke, Brayford Meer, or their communications, we find those most subject to be drowned are as follows.

On the south of Fossdyke are Lincoln Holmes, Bootham low grounds, Skellingthorpe low grounds, and part of Saxelby pasture: on the north of the Fossdyke are part of the Lincoln Common, Burten Fen, South Carlton Fen, North Carlton Fen, and a small part of Broxholme, Haddow, and Saxelby low grounds, upon the Till.

The surface of the grounds above mentioned are at a variety of elevations above the level of Fossdyke water; yet the greatest part thereof were less than 3 feet, and we found no considerable quantity but what was at the time of this view 1 foot and upwards above the Fossdyke (the greatest part being from 1 foot to 1 foot 6 inches), except the Hassocks in Lincoln Holme (being in a manner a bog), a small part of the low slade which extends from the Fossdyke to Bishop Bridge on Lincoln Common, and a small quantity in Saxelby pasture opposite to the Till, which were but little elevated above the Fossdyke surface. But the lowest ground of any consequence, is a slade extending from Cuckoo Pool to Saxelby pasture, which appears to have been the course of the Till before the Fossdyke was originally cut; this was from 5 inches to about a foot above the said Fossdyke surface. At the time

when this view was taken, there was at a medium, as before mentioned, 4½ inches water upon Brayford Head; from the best information there is scarcely ever less than 3 inches, and in great winter floods, full 4 feet; so that it may be reasonably conjectured, and we have been so informed, that in the spring of the year, and at all other times until the said flood waters, which have expanded themselves over that large tract of low grounds above Lincoln, are exhausted, there can seldom be less than 10 inches water thereon.

The principal opening for the discharge of those waters of the Witham, and from this tract of land under consideration, is through Lincoln High Bridge, which, in the narrowest part, is no more than 15½ feet; besides which, are Sincil Dyke and the two Gowt Bridge Drains aforesaid, which, though greater in width when taken together, yet, from lying considerably higher, and from those drains being very defective, are not capable of discharging more water than the High Bridge singly.

From hence it appears, that the low lands before mentioned, when once overflowed, their drains having an open communication with each other, must remain under water during the winter, and a great part of the spring season, and are without the compass of a complete drainage in their present situation.

Imbanking and engines are a general method of drainage, which may be put in practice where nothing else can; but the certain expense, and uncertain effect thereof at critical times, have made all drainers prefer the use of natural means, where those natural means can be had.

On examining the Fossdyke, we find the general bottom to be about 2 feet 8 inches below the level of Brayford Head, in some few places, less; but as they are only short distances, they will easily be reduced to a proper depth by dredging, so that there is wanting 10 inches of depth in order to complete the navigation to 3 feet 6 inches; for the addition that will be made by 3 or 4 inches of water constantly going over Brayford Head, will give a sufficiency of free water for navigating vessels drawing 3 feet 6 inches. In order, therefore, to give the Fossdyke this necessary addition, and at the same time to drain the lands in question without detriment to any other, we propose a scheme founded on the following facts.

1st. That from the surface of the river Witham, at the lower mouth of Sincil Dyke, to the surface of the water of Brayford Meer, when at its ordinary summer's height, is a rise of 14 inches; but from the surface of the river at Stamford to the same place, is a rise of 1 foot 7 inches and a half; and from the surface of the Brayford Meer, to the surface by Bailey's Sluice, is 2 feet 5½ inches.

2d. That from the surface of Brayford Meer, to the surface of the river Witham, at the upper mouth of Sincil Dyke, which runs under Bargate Bridge, is a rise of 1 foot 6 inches.

3d. From the surface of Brayford Meer, to the surface of the river Witham at Brace Bridge, is a rise of 3 feet 2 inches.

4th. From the natural stanch of Brayford Head, to the bottom of the river at Brace Bridge, forming a natural stanch, there is a rise of 2 feet 6 inches.

5th. That from Brayford Head, to the bottom of Sincil Dyke Drain, at its highest part, near Bargate Bridge, is a rise of 1 foot 7½ inches; and from Brayford to the mean highest bottom of the Gowt Bridge Drains, is 1 foot 3½ inches.

N.B. At the time of this view, the Sincil Dyke and two Gowt Bridge Drains were all running about 3 inches over the highest points.

6th. We found, from our levels and observations, that all the low grounds adjoining upon the Till, are on so high a level above the surface of the Fossdyke, that they will have a drainage therein on the decline of floods, except about 40 acres,

contained in a narrow screed by the old course of the Till side, from Haddow Bridge, about half a mile upwards, the lowest part of which we found 13 inches above the surface of the Fossdyke, and about 20 acres more lying in a slade a little higher up, on the north side, the lowest part of whose surface was 9 inches only above the Fossdyke; we also found that the only conveyance for the Till opposite this slade, was an artificial cut or ditch, about 3 feet and a half wide in the bottom, and at this time quite dry.

7th. That having examined the several drains that fall into the Fossdyke, west of the Till, we find that the bottom of Dodington Drains (by its tunnel) is 1 foot 6½ inches higher than the surface of the Fossdyke; Thorney Drain bottom, near the tunnel, is 6 inches above the said surface of the Fossdyke; but the bottom of the said drain, which rises gradually at about ¾ of a mile distance therefrom, is 4 feet higher than the same. The bottom of the first drain on Kettlethorpe Moor, near its tunnel, is higher than the surface of the Fossdyke by 3 feet 2 inches; the 2d, by 1 foot 10 inches; and the 3d, by 2 feet 2 inches; the bottom of the drain between Kettlethorpe and Fenton Moor, by its tunnel, is 1 foot 1½ inch, and that on Fenton Moor is 1 foot 7 inches higher, by its tunnel, than the surface of the said Fossdyke; and all the said drains rise considerably, as they advance into the land, and the said land is also, in general, considerably higher than the bottoms of the said drains; so that it is evident that none of these drains, nor the lands through which they pass, can be affected by a rise of 10 inches in the Fossdyke above the surface it then had, viz. 4 inches and a half above Brayford Head.

SCHEME FOR A GENERAL DRAINAGE AND NAVIGATION.

1st. To embank both sides of the Fossdyke, where wanting, from Brayford Meer to the river Till, making all good, 5 feet higher than Brayford Head (which, as the flood waters of the Witham are proposed to be kept out of this part of the river, will be sufficient), and cutting off all communication with Swan and Cuckoo Pools.

2d. To scour out and enlarge Sincil Dyke, from its lower mouth near Stamp End, to the place where the first or northernmost Gowt Bridge Drain falls into the same, bringing up the bottom upon a dead level with the bottom of the river Witham at Stamp End, making it 25 feet wide at bottom, with proper slopes. Then to scour out and enlarge the said Gowt Bridge Drain, from the said Sincil Dyke to the Witham, continuing the bottom thereof upon the same dead level, and 15 feet broad, with proper slopes or batters; and to continue the same underneath the Witham, by means of an underground tunnel or fox, 14 feet wide, and 3 feet deep, with pointing doors on the east end, and draw doors on the west end thereof: the river Witham to be entirely banked off from falling into this drain. A new drain, of the same depth and capacity, to be continued from the Fox to such part of Swan Pool as is as deep as the drain.

A drain of the same dimensions to be continued from Swan Pool to Cuckoo Pool. The ground taken out of the new cuts from the Witham to be disposed of bank-fashion, leaving forelands of 3 feet on each side of the cuts.

3d. To strike out a drain from Swan Pool, or from any point of the drain before mentioned, between Swan Pool and Cuckoo Pool, that shall be in a proper direction for crossing the Fossdyke, and to pursue the same to Bishop Bridge. This drain

should be 14 feet bottom, with proper slopes, and to rise from the aforesaid dead level one foot between Swan Pool, or the point aforesaid, and Bishop Bridge; the said drain to communicate under the Fossdyke by means of a subterraneous tunnel, or fox, of 12 feet wide, and 3 feet high; the earth of the cut from Swan Pool to the fox, to be disposed of bank-fashion, with forelands of 3 feet.

N.B. A bridge will be wanting over this drain on Lincoln Common.

4th. To erect a lock, with two pair of gates, upon the passage between Mr. Ellison's wharf and Brayford Meer, the gates to be pointed towards Brayford Meer; the whole to be built high enough to pen the water of the highest floods of the Witham from flowing into the Fossdyke.

5th. To scour out the river Witham, where wanting, from Brayford Meer to Brace Bridge, and to embank the same on the west side, so as to be flood-proof, and continuing the same on the south-west side of Brayford Meer, to join the south side of the said lock; and to construct a similar bank on the north side of the said lock to the high land on the north side of Fossdyke, making the said banks 30 feet seat, 6 feet top, and 6 feet high; the river between Brayford Meer and Brace Bridge, to be made at least 36 feet wide, and its bottom so deepened as to form a regular inclined plane, one foot deeper than the present level of Brayford Head at that end thereof, and of the present depth at Brace Bridge. The bank to be formed partly from its back drain 10 feet wide at top, 4 at bottom, and 3 deep; the rest from the said widening or deepening the river, and to be placed 40 feet from the border of the river.

6th. To further scour out and enlarge the Sincil Dyke between the two lower mouths of the Gowt Bridge Drains, so as to be of the same dimensions as before specified for the lower part thereof, and from the lower mouth of the second or southernmost Gowt Bridge Drain, to scour out and enlarge the Sincil Dyke to its upper mouth at the river Witham, so as to be 12½ feet bottom, with proper slopes, and the bottom to be carried nearly upon a dead level from the said point to the river Witham. And in like manner and proportion, the second or southernmost Gowt Bridge Drain to be scoured out, and enlarged, from the said point to the river Witham, and to erect two stanches; one upon the upper mouth of the Sincil Dyke, the other upon the upper mouth of the said Gowt Bridge Drain, both opening into the river Witham: the Sincil Dyke stanch to be gauged to 1 foot 4 inches higher than the present level of Brayford Head; that is, lower by 3½ inches than the highest part of the present bottom of the said drain, and the Gowt Bridge stanch to be gauged 1 foot 2½ inches above Brayford Head; that is, one inch lower than the medium of the two Gowt Bridge Drain bottoms; the said stanch to have a clear waterway of 12½ feet each, and their sills to be laid as low as the bottoms of their respective drains.

7th. To erect a stanch at or near Lincoln High Bridge, on the west side thereof, the top of which to be gauged to 10 inches above the level of the present Brayford Head, and to be filled up with doors capable of allowing a clear water-way of 15½ feet at least, and the sills of these doors to be laid at least 2 feet 8 inches below the level of the present Brayford Head; after which, the said shoal of Brayford Head to be removed, and the whole contents of the river, between Brayford and Lincoln High Bridge, to be taken away as deep as the sill of the said stanch.

N.B. If, instead of erecting the said stanch at the High Bridge, it be erected 100 feet to the west of the said bridge, with a pair of doors pointing towards Brayford Meer, it will form the upper gates of a lock, for making a communication between the Fossdyke and intended navigation from the High Bridge to Boston.

8th. To scour out, enlarge, and embank the Till, from its junction with the Fossdyke at Haddow Bridge, to about 1 mile above the same, so as to be capable of

sustaining and confining the greatest floods within its banks, and to lay a small subterraneous tunnel of about 6 inches square under the same, to convey the down-fall and soakage waters from the low grounds lying west thereof, into Burton main drain, by which they will be drained in conjunction with Carlton and Burton Fens, &c., without any annoyance thereto.

N.B. It is proposed that the said cut shall be at least 12 feet wide at bottom, and its banks 5 feet higher than Fossdyke surface at low water.

9th. The gauged bar of Torksey Lock (being 10½ inches in height) to be removed, and the framed bar to become the gauge at Torksey.

10th. To erect a pillar of stone in or by the side of Brayford Meer, whose top to be 1 foot 2 inches above the level of Brayford Head; to be so placed that the water thereof may flow freely round and upon the said stone, with a set-off or conspicuous mark, 1 inch below the said top.

THE OPERATION OF THE FOREGOING CONSTRUCTIONS.

1st. As there appears, from the facts before stated, to be a fall from the surface of Brayford Meer to the surface of the river Witham, at the lower end of Sincil Dyke, of 14 inches, in its common summer's state; and that from the lower end of Sincil Dyke to Stamp End there is a further fall of 5½ inches, chiefly owing to the obstructions of the river Witham between those two points; and also a yet further fall from thence to Baily's Sluice, of 10 inches;—it follows, that, whenever the Commissioners for the navigation between Lincoln High Bridge and Boston shall be pleased to execute this part of their undertaking, according to the act, there will then be a much more considerable fall obtained; or, in the meantime, if they will suffer the drainers above Lincoln to deepen the river between Stamp End and Sincil Dyke, that then this 5½ inches shall be added to the former 14 inches, so as to make 1 foot 7½ inches fall from Brayford Meer to the lower mouth of Sincil Dyke. However, not to build this scheme upon the probable execution of another, we will, for the present, suppose every thing within that act to stand as it now does, still there will be a fall of 14 inches gained to Brayford Meer; and since the general surface of the low grounds (before specified) that drain into Brayford Meer were from a foot to 18 inches above the surface of that meer, at the time of this view (Brayford Meer being then 1½ inch higher than its lowest state), it follows, that there will be a fall of above 2 feet 6 inches from the general surface of the low lands to their out-fall at Sincil Dyke tail; and as the flood waters of the Witham (which, for want of a sufficient discharge at Lincoln, have chiefly contributed to the overflowing of the same) will be held off by the proposed bank from Brayford Meer to Brace Bridge, there is no doubt, but that the fall above mentioned will be sufficient for the general drainage of the low grounds aforesaid. It is true that some places, within the low grounds afore specified, lie lower than the general surface by several inches; but as the quantities so circumstanced are of no considerable extent, and as those very pieces will, by the execution of this scheme, be in better condition, as to drainage, than the greatest part of the low grounds now are, no reasonable objection can be drawn against the scheme in general from those particular places; for as to the low slade of the old Till, between Cuckoo Pool and Saxelby Pasture, it may be provided for by carrying the main drain through it, and will, of consequence, be most early in receiving benefit; and yet this slade will, at a medium, lie 2 feet, and its very lowest

parts, next Cuckoo Pool, 19½ inches, above summer's water, even supposing nothing was to be done below the tail of Sincil Dyke.

2d. With respect to the low grounds lying upon the Till, the Fossdyke water, being raised 10 inches by the stanches at Lincoln High Bridge, will pen 10 inches upon the mouth of the said river in dry seasons, at which time it has no currency; but as we do not find any of those grounds will be affected thereby, except the small quantity before specified, and as, in times of rains and floods, or whenever the water coming from the Witham would, in its present condition, rise 10 inches above its lowest state (which, as has been shewn before, is the greatest part of the year), the Till will have a much better out-fall than it now has; for, in the first place, as the Witham waters (which at present rise upon them near 4 feet in times of floods) will be entirely shut out from the Fossdyke, whenever they would over-ride the same, by reason of the lock near Brayford Meer, and banks mentioned in the 5th article, as those waters themselves will be much sooner discharged than at present by the proposed stanches, as the gauge bar at Torksey Lock will be removed; and as it is also proposed to confine the flood waters of the Till with banks of a sufficient height and strength to sustain them till they are fully discharged into the Fossdyke, the low grounds on each side the said Till can then be no otherwise annoyed than by the down-fall and soakage waters, which will be very inconsiderable, as the earth for making the said banks is of a strong and tight texture, and as an ample provision for carrying off these down-fall and soakage waters is made by the subterraneous tunnel to be laid under the Till into Burton Drain, it follows, that, upon the whole, the discharge of the Till waters will be considerably facilitated and improved, and the drainage of the low grounds under consideration, that lie thereupon, will be completed.

3d. The grounds west of Saxelby, which drain into the Foss, will, in like manner, have the surface of that river raised 10 inches upon the tail of their drains, in dry seasons; but as we find none of them that will be affected by that rise (very little by double, nay, even treble), and as the Foss will no longer be raised by the Witham floods, and those floods sooner run off by the gates of the proposed stanches, it will be kept at a more constant height, being no otherwise affected than by the influx of their own and the Till waters, which will find their way either into the Trent or Witham waters, as soon as either river is so settled as the Foss water will over-ride them; so that, upon the whole, these lands being freed from the high floods which principally annoy them, will be greatly benefited, and ought, in strictness, to contribute towards the making of the said lock and bank.

4th. The proprietors of lands above Brace Bridge will also receive benefit by this construction; for since there is 18 inches fall from the upper mouth of Sincil Dyke to Brayford Meer at ordinary seasons in summer, it is plain, that an additional pen at the said meer will not sensibly affect the level of the water at the entrance of Sincil Dyke; on the contrary, when the widening and deepening of the river between Brayford Meer and Brace Bridge is performed, the water will then run off lower than at present; and since the tops of the stanches at Sincil Dyke and one of the Gowt Bridge Drains are to be lower than their respective bottoms now are, and the capacities of those drains greatly enlarged, it is manifest, that, though the stanches were never to be drawn at all, the water would have a better passage than it can now have; but, as the preservation of the banks, proposed in Article 5 of the scheme, depends upon drawing the stanches, the proprietors of the aforesaid low grounds will not be wanting in drawing them when necessary, which will afford a great easement to the passage of the water far beyond any thing they have ever had: and, for the

prevention of disputes between the land-owners and navigators, it is proposed that whenever the water of Brayford Meer covers the stone pillars proposed in Article 10, that the gates of the stanches shall be drawn, or so many and so much as shall be found necessary to reduce the waters 1 inch below the top to the mark aforesaid; and whenever the water shall settle below the said mark, then the gates of the said stanches to be shut down, or so many and so much as to prevent its falling below the said mark, which business will be regularly done by a person properly appointed and authorised for this purpose.

5th. The undertaking for drainage of the fens, and navigation between Lincoln High Bridge and Boston, will also be benefited by this scheme; for since the great object of that scheme was to preserve the living and flood waters, particularly those of the Witham, for scouring of the out-fall, by this means they will be preserved, and brought down by the readiest passage, instead of being spread over the fens and low grounds above Lincoln, by which their force is broke, and a great part thereof evaporated by the sun and winds. It is true, that the Fossdyke being kept up 10 inches higher, will expend somewhat more water in the passage of each vessel; but, on the other hand, the communication between the Fossdyke and the Swan and Cuckoo Pools being stopped, the evaporation from the extended surface thereof will thereby be saved: and the matter being reduced to a fair calculation, it appears, that this evaporation is greatly more than sufficient to supply the difference of lockage, leakage, and soakage, that will probably arise from an increase of height of 10 inches in the Fossdyke surface.

6th. This scheme will also be of great benefit to the navigation of the Fossdyke, not only in giving the necessary quantity of water to render it complete in all seasons, from the river Trent to Lincoln High Bridge, but in excluding such extra quantities of water, as, in time of floods, not only annoy the navigation, but the lands adjoining thereto, which inconvenience must have subsisted ever since this cut was originally made, and, consequently must always have been the foundation of disputes and dissatisfactions between the navigators and land-owners thereto adjoining; and upon the present scheme, it appears, that the interest of both parties coincide, it is greatly to be wished and hoped, that they may as heartily join in the expense of executing the same upon an equitable footing; and lest any jealousy on the part of the land-owners should obstruct the execution of a project so much to their advantage, as supposing it more calculated to serve the navigation than themselves, we think it expedient to declare, that nearly the same advantages can be procured to the navigation as will be obtained in the scheme before specified, without prejudice to the present state of the land-owners' drainage, and that to accomplish as good a drainage as is proposed by this scheme will cost the land-owners considerably more, than if done conjunctly with the proprietors of the navigation.

AN ESTIMATE OF THE WORKS MENTIONED IN THE PRECEDING SCHEME.

	£.	s.	d.
Art. 1st. To making good both banks of the Fossdyke, from Brayford Meer to Saxelby Pasture, opposite the Till	463	15	0
Art. 2d. To scouring out and enlarging Sincil Dyke, from its lower mouth to the first Gowt Bridge Drain (including contingences)	172	15	8
To scouring out the first Gowt Bridge Drain, from Sincil Dyke to the Witham, and the contingency of under-pinning the arches under which it passes	53	0	0
To making and laying the fox under the Witham	208	12	0
To making a new drain from the fox to Swan Pool	63	2	0
Carried over	961	4	8

	£.	s.	d.
Brought over	961	4	8
To making a drain from Swan Pool to Cuckoo Pool	84	0	0
Art. 3d. To making a new drain from or near Swan Pool to Bishop's Bridge	145	4	0
To making and laying the fox under Fossdyke	190	0	0
To making a new hauling-bridge over the drain, and a wagon-bridge for the road to Pywipe inn	40	0	0
Art. 4th. To constructing a lock between Mr. Ellison's wharf and Brayford Meer	400	0	0
Art. 5th. To scouring out and enlarging the river Witham, and embanking the same on the west side from Brayford Meer to Brace Bridge, and to embanking Brayford Meer on the south west side, from the north end of the aforesaid bank to the lock, and from the lock across the high land in the north, including the south drain	587	19	0
Art. 6th. To scouring out and enlarging Sincil Dyke, between the lower mouths of the Gowt Bridge Drain	12	0	0
Scouring out and enlarging Sincil Dyke from the second Gowt Bridge Drain to the Witham, and the contingence of under-pinning Bargate bridges	63	5	0
To scouring out and enlarging the second Gowt Bridge Drain, from Sincil Dyke to the Witham, and the contingence of under-pinning the arches under which it passes	42	10	0
To erecting two stanches, one at the upper mouth of each of these drains, at 180*l.* each	360	0	0
Art. 7th. To constructing a fixed stanch, with draw-door, at or near the High Bridge, at Lincoln	200	0	0
To scouring out Brayford Head, and deepening the river from Brayford Meer to Lincoln High Bridge, including the rebuilding of walls	195	0	0
Art. 8th. To deepening and enlarging the Till, from Haddow Bridge one mile upwards, so as to be 12 feet wide at the bottom, and making strong and effectual banks on each side, at least five feet above the low water in the Fossdyke	168	6	0
To making and laying a subterraneous tunnel under this dyke and banks, 6 inches square within	4	0	0
To making a catch-water drain and bank on the lower side, at the upper end of this new cut, to reach the high land on each side the same, which will conduct all the flood-water therein	8	5	0
Art. 9th. To taking away the guage-bar at Torksey Lock	0	5	0
Art. 10th. To erecting a stone pillar for a guage height in Brayford Meer	5	0	0
Art. 11th. To supervising, and unforeseen contingences, at 10*l.* per cent.	350	0	0
	£. 3816	18	8

Doncaster, October 16, 1762.

JOHN GRUNDY.
J. SMEATON.

We come now to give an answer to the following question, communicated to us by Mr. Amcotts.

" Mr. Gollman desires to know if the Sincil Dyke and the Gowt Bridge Drains were to be scoured out and deepened to the depth of the new intended river below Lincoln, with gates erected at the upper end 2 inches higher than the present height of Brayford Head, a channel to be made from those places into Brayford Meer, to communicate with the Fossdyke; the gates to be opened at the time of floods, the shoal at Brayford Head to be removed, and gates or a ware to be erected by the side; the top of which to be 10 inches lower than the present height of Brayford Head, with a waste board to be placed thereon in dry seasons; what effect such a scheme would have on the Fossdyke navigation?" The scheme here proposed, in some respects, is the same as the scheme proposed by us, as before specified, but with this essential difference, that our scheme proposes to give the Fossdyke navigation an addition of 10 inches constant water above its lowest state, and a complete drainage to the lands; the other to keep it constantly at its lowest state, with an imperfect drainage of the lands.

From the time the rains usually fall in September or October, to the running off and evaporating the flood waters in May, the Fossdyke navigation is generally as complete as can be wished for; but were the flood waters run off by the proposed gates as they come down, the Fossdyke would never be above its lowest gauge, except at the top of high floods; which, as they would be uncertain, would be of little use to the navigation: for, as Brayford Head is proposed to be reduced 10 inches, except in dry seasons, this would constantly run off the common current waters; and perhaps often more than that after the gates had been drawn, so that at those times the Fossdyke would be reduced to a lower state than it ever can be at present, all which, in consequence, would be a great detriment thereto; besides, no man as a navigator would choose to subject his water to the mercy or misconduct of others, or the want of necessary repairs of gates, stanches, or other works, without any prospect or probability of any advantage arising therefrom.

And with respect to drainage, the scheme proposed by the aforesaid question is extremely imperfect, almost all the requisites for a complete one being omitted, that is to say, the necessary embanking of the rivers, &c. to keep out the flood and barrier waters, and the proper means of carrying off the downfall and soakage to a surface sufficiently below the soil of the lands to be drained; for nothing more is thereby proposed towards accomplishing these great ends, than forming stakes to ease the flood waters (which is as fully and amply provided for in our scheme as in this), but very far from totally removing their effect upon the low lands in question; so that, after the execution of such a plan, the low grounds of Boatham, Skellingthorpe, Saxelby, Lincoln, Burton, Carlton, &c. would yet be liable to be overflowed in all wet seasons, and in dry ones the proposal itself points out no advantage in drainage.

JOHN GRUNDY.
Doncaster, Oct. 16, 1762. J. SMEATON.

CONCERNING THE DRAINAGE OF THE LOW GROUNDS OF TORKSEY AND FENTON, WHICH DRAIN BY TORKSEY BRIDGE SLUICE.

As the drains of those grounds have no communication with the Fossdyke, till below Torksey Lock, their out-fall is in effect into the Trent; and therefore it is of no concernment to them what the height of the Fossdyke surface is between Torksey and Lincoln.

Torksey Bridge Sluice (the outlet) lies on the south side of the Fossdyke, and also the drain leading thereto, which extends eastward about a furlong, and there divides, one branch turning to the right, through Fenton Moor, the other to the left, through Torksey low grounds, which, lying on the north side of the Fossdyke, communicates by means of a subterraneous tunnel or fox, each drain having a separate sluice near the point of partition, which shuts reciprocally in case either water should over-ride the other. Each of these drains receives the down-fall waters from an extensive tract of country, and, in consequence, in times of great rains, when the Trent is so full as to keep shut the doors of Torksey Bridge Sluice, those waters overflow their respective drains, and consequently, the lowest lands near their out-fall; and if the rains are violent and lasting, and the Trent continues high, as it sometimes does for weeks together, the waters, all this while accumulating within, rise to a great bulk and height. As, therefore, the

cause must always remain, the effect will do so too; the only thing that can be done, in the present case, is to give the water a passage sufficiently free, that whenever the Trent becomes lower than the waters within, they may run off as soon as may be. Those ought to be the views of them who undertake the drainage of those tracts of land. The only question that relates to the Fossdyke is, whether the proprietors thereof have made provision for discharging those waters as amply as the proprietors of lands have made for themselves to bring the water thither.*

The sluice at Torksey Bridge, and the fox under the Fossdyke, are works constructed by the undertakers of the Fossdyke; the sluice at the tail of Fenton Drain, and that at the tail of Torksey Drain, leading into the fox, are old works constructed by the land-owners to serve their own occasions. The sluice at Torksey Bridge consists of one arch or tun of 7 feet wide, which having a staple-post of 1 foot wide in the middle, forms it into 2 apertures of 3 feet wide each, which are shut by two falling doors; the floor of this sluice lies lower than Fenton Sluice by 1 foot 9 inches, lower than the sluice entering the fox by 1 foot, and lower than the lowest lands to be drained thereby 2 feet 1 inch. The width of Fenton Sluice is 2 feet 11 inches; the sluice leading to the fox consists of two doors, which are 2 feet 1 inch wide each. The width of the fox is 2 feet 10 inches by 2 feet high, and the entry thereof lies 8 inches lower than the threshold of the sluice adjoining. 1st. The question is, therefore, whether Torksey Bridge Sluice is equal to the capacity of Fenton and Torksey Fox Sluice taken together in point of discharging water; and, 2d, whether the capacity of the fox is equal to the capacity of the sluice leading thereto. Having subjected this matter to calculation, we find that, at a mean height of the flood waters upon Torksey (which is the lowest lands), Torksey Bridge Sluice will run more water than Torksey Fox Sluice and Fenton Sluice put together, by above 200 cubic feet in a minute, which arises from its lying so much lower; but that, in the like case, the fox will not run so much water as the sluice adjoining thereto; but that if another equal tunnel is thereto added; that the capacity of the two will exceed the capacity of the said sluice by above 500 cubic feet in a minute. We therefore recommend it to the Fossdyke proprietors to add another fox of equal capacity, or to double the capacity of the present; but as we are of opinion the foundation of the grievance does not so much consist in want of capacity in the fox to discharge the water, as in the sluice itself to run it off low enough, we are of opinion, that at the same time the capacity of the fox is enlarged, that the land-owners should lay the threshold of this sluice as low as the out-fall sluice at the bridge, and that the entry into the fox should be made conformable thereto. In this case, the mean capacity for discharging water will not only be doubled, but with the advantage of running it 1 foot lower than at present, which will be above 2 feet lower than the lowest lands that drain thereby.

N.B. It must, however, be considered, that it is but lately that a new tunnel of 2 feet wide at Harrow Head Bridge has been added; the whole capacity of that bridge was, before that time, only one tunnel of 2 feet 2 inches wide, the paved floor whereof lies at least 6 inches higher than the sluice at the fox; and as the bulk of

* In constructing works by act of Parliament, if ample provision is made for the preservation of private property, tothe satisfacti on of the proprietors at the time, that if, afterwards, those proprietors extend their views in order to improve their property, that the public undertakers at their own expense to make all such alterations in their works that the land owners should think fit; if this was the case, a public undertaker would never know when he had done.

the water that comes to that sluice comes through this bridge, it must be acknowledged that the capacity of the fox to discharge water at the time it was made was superior to the capacity of this bridge to let down the water to it.

The meeting of the Torksey and Fenton waters, in a direction nearly opposite, is a manifest incongruity; but, as the place of meeting is pretty deep, and wider than the rest, it forms in some measure a reservoir common to both, and, if perfectly so, it would signify little in what direction the water comes in; but as it appears to us, that as the land drains and sluice lie lower on the Torksey than on the Fenton sides, that the Fenton waters will generally over-ride the Torksey: this will deserve a remedy that will also cure the other defect at the same time. We, therefore, propose that a new tun of 4 feet wide and 3 feet high, with one door, to be added to the present sluice at Torksey Bridge, on the south side thereof, and making a partition between the old and new tuns, and to bring the present common drain in an oblique direction to the new tun, and to carry a new drain from behind the said partition, from the old sluice to the tail of the fox, stopping the present communication near Fenton Sluice; by these means the waters will be kept quite separate, which will be a great improvement to the present drainage of the low grounds under consideration: and, as it will lay the foundation for completing the drainage thereof, as far as nature will allow, in our opinion, the land owners ought to be at part of the expense of the aforesaid new sluice and drain. An obvious mistake has also been committed in turning the tail drain leading from Torksey Bridge Sluice into Foss, below the lock, at a square elbow; but if it be considered, that this drain, being wider than the clear water-way of the sluice by 3 feet, and deeper than the floor thereof, the velocity of the water is so much less on account of a greater capacity, that the ill effect of this inconsistency is not, in reality, so great in the present case as it may seem; however, as this drain must be widened near the sluice, on account of the new tun, to give a freer passage to the water, and to remedy this defect both at once, we advise the turn of the said drain to be made by a quarter round instead of a square elbow.

JOHN GRUNDY.
Doncaster, October 16, 1762. J. SMEATON.

To the Gentlemen assembled at a General Meeting on the 2d day of September, 1782, *for considering of a Plan of Improvement of the Navigation of the River Fossdyke, and for Improving the Drainage of the Lands on each side the said River.*

GENTLEMEN,

Since my arrival at Lincoln, on Thursday evening last (as desired by Mr. Lyon), I have diligently employed myself, in conjunction with Mr. Carlton, and Mr. Pilley, agent for Mr. Ellison, who were appointed to conduct me, in reviewing the different parts of the extensive scheme of drainage and navigation, that was formed by Mr. Grundy and myself in the year 1762, in order to prepare myself to assist you, gentlemen, in the reconsideration thereof.

It is a subject indeed so extensive, that the time has been fully employed in going over some of the most material and leading parts thereof, and it will necessarily take a further length of time to enter into that accurate and digested consideration that it had from Mr. Grundy and myself at the time abovementioned, being now 20 years ago. But, as upon this revisal, I find a very striking difference in the situation of the leading circumstances attending this business, I think it necessary to lay those

open to your consideration, because, unless some means are found, by which the impediments, that since that time have been placed in the way, can either be removed or avoided, it seems fruitless to enter into any scheme for the general drainage of the low grounds west of Lincoln: for it does not appear to me, that as things now stand, any such material improvement can be made therein, as shall be likely to answer the cost of doing it.

When the scheme of 1762 was under consideration, the Witham navigation act from Lincoln to Boston was then subsisting, with a clause therein, that no staunch or land-door should be erected between Washingborough Ferry and Lincoln High Bridge, which should not be at least 2 feet below the lowest grounds in Canwick Ings, as, by reference to the act, will more fully appear. At present, I find a lock and a staunch below the lower mouth or out-fall of Sincil Dyke, which by the former scheme was to be the out-fall of the drainage waters of the lands west of Lincoln into the river Witham, the top of the gates or doors of which staunch is higher than the surface of the said lowest grounds of Canwick Ings, and, consequently, they are, as it appears to me, full 2 feet higher than according to the said clause they ought to be (the doors or gates of the lock being still higher), and the top of the gates or doors of the said staunch being full as high as Brayford Head was in 1762. The fall for the drainage waters from Brayford Meer to the lower mouth of Sincil Dyke is now taken away and lost, the water being now so near upon a level at the two said points, as to be totally insufficient towards any material improvement in point of drainage.

In order, therefore, to recover the fall for the proposed drainage waters that then subsisted, it appears to me absolutely necessary, either to remove the said staunch, whereby the waters may have their natural descent in its ancient course through the city of Lincoln, or to carry the out-fall drain so far below the limits of the Sincil Dyke as to pass through some part of Canwick Ings, and fall into the present course of the river Witham below the said lock and staunch; that is, where the same, on mature consideration, shall be deemed the most eligible.

The latter way appears to me at present preferable, not only as it would not interfere with the present navigation, but the drainage waters would be less liable to be over-rode by the living waters of the Witham.

I am, Gentlemen,

Lincoln, September 2, 1782. Your most humble servant,

J. SMEATON.

To the Gentlemen that attended a General Meeting on the 2d day of September, 1782, *at the Reindeer at Lincoln, for Considering of a Plan of Improvement of the Navigation of the River Fossdyke, and for Improving the Drainage of the Lands on each Side of the said River.*

THE REPORT

Of John Smeaton, Engineer, upon the Improvement of the Navigation of the River Fossdyke, and for Improving the Drainage of the Low Lands on each Side of the said River.

In the year 1762, Mr. Grundy and myself were employed by Mr. Ellison to form a scheme for the improvement of the Fossdyke navigation, and at the same time to improve the drainage of the low grounds west of Lincoln, of which business we

acquitted ourselves by our joint report, dated the 16th of October of that year; contrariety of opinion among the parties interested at that time prevented the execution of the scheme then proposed.

In August last I was invited to reconsider the said scheme, and to assist the gentlemen interested in this business in forming such a one, as at this time should be useful and agreeable to all parties, and to attend their public meeting at Lincoln for that purpose upon the 2d of September last, which accordingly I did.

On reviewing the subject previous to this meeting, I perceived that, upon supposition of the best possible drainage, compatible with the improvement and even *subsistence* of the Fossdyke navigation, the scheme then proposed appeared now to me to be very complete upon the circumstances and situation in which things then were; but that at present, the case is so very much altered, that the very ground and foundation upon which we built the principal merit of the scheme, so far as it related to drainage, is now subverted; for the ultimate drainage of all the grounds in question being into Brayford Meer, and as at that time there subsisted a fall, in dry seasons in summer, from Brayford Meer, through the city of Lincoln, to that part of the river Witham where the tail of Sincil Dyke falls into it, of 14 inches, and a further fall then of $5\frac{1}{2}$ inches more to Stamp End, and which was still greater down to the point where Bailey's Sluice Drain falls into the same, it appeared to us, that the addition of this fall to the low grounds that then drained into Brayford Meer, when judiciously managed, would make the drainage thereof very complete. Nor were there at that time any reason to fear the loss of this fall, but rather an expectation of gaining more; for though the act of parliament for draining the lands, and making or improving the navigation from Lincoln High Bridge to Boston, had then passed; yet, as the advantages that might in future possibly result from this fall to the city of Lincoln, and low grounds west thereof, were guarded by a clause, enacting that no staunch or land door should be erected between Washingborough Ferry and Lincoln High Bridge, which should not be at least 2 feet lower than the lowest grounds in Canwick Ings, there could then, in regard to this fall, be no apprehension of difficulty; but, contrary thereto, on this view I found a lock below Stamp End, now called Lincoln Lock, accompanied with a staunch, erected across the river Witham, abreast of the said lock, and consequently below the tail or out-fall of Sincil Dyke, into the said river; the top of the said doors of which staunch was not only higher than the medium surface of the lowest grounds in Canwick Ings, and, therefore, full 2 feet higher than according to the said clause they ought to be, but also higher than the natural staunch of Brayford Head was in the year 1762, and occasioned a pen of the water in Brayford Meer, higher by $1\frac{1}{4}$ inch than it was at that period: in consequence, as, in this state of things, Brayford Meer is rather higher than lower than it was, and the fall that might have been required totally taken away and destroyed, it follows, as things now are (Brayford Meer being still the ultimate out-fall of the drainage of all the lands in question), that no material improvement can be made therein.

These consequences I did myself the honour of laying before the gentlemen assembled at the meeting of the 2d of September last; and withal observed, that unless either Lincoln Lock and Staunch, as it now stands, can be removed, or a new out-fall procured for Sincil Dyke, so as to fall into the Witham below the said staunch, it will be to no purpose to think of any schemes of drainage that will be likely to be attended with benefit equal to the expense.

These matters being fully considered by the gentlemen present, and seeing difficulties in either way, and it being the general sense of the meeting, that it would be a considerable improvement to their low grounds, if they could more early in the

spring be cleared and ridded of their water, without destroying the navigation through Lincoln, I then observed, that on supposition Lincoln Staunch and Lock was removed still higher up the stream from its present place, above the tail of Sincil Dyke, I did not doubt but to be able to draw up a scheme that would not only preserve, but greatly improve the navigation through Lincoln, greatly benefit the drainage of the lands without embankments upon the Witham, but also give every competent improvement to the Fossdyke navigation, and that by expedients to which I could not see any reasonable objection.

This scheme, after fully and deliberately considering, I now beg leave to propose.

The lands at present under consideration are the general reservoir of the waters that in great floods are brought down by the river Witham from the upland country, through a course of above 40 miles, the passages for which, through Lincoln, relative to the fall it has, are at present so very inadequate to the discharge of this water as fast as it comes, that it extends over a vast tract of ground of many miles square.

In the year 1762, it was known to have risen above its summer drainage height about 4 feet perpendicular, but, upon this view, this water, from marks that were shewn me, its height had been more than 5 feet 9 inches above the former mark, which shews that the banks necessary to restrain and carry off so great a body of water as fast as it comes would be required of such a height and strength, that I am of opinion (with the land owners) it would be not only very difficult and very expensive to confine, but be matter of objection to the drainage of the lands upon the Witham below Lincoln.

In a dry season the lands in question become completely drained by the present outlets, but, as the ultimate level of Brayford Meer, at which the fresh waters of the Witham can be discharged, is but a few inches lower than the lowest grounds proposed to be drained, when the top waters are so much run off, as that the drainage is almost completed, the quantity capable of being then discharged but so little exceeds the influx of the Witham from the higher country, that was it not for the joint action of the sun and winds, the surface of these lowest tracts would never become dry, so as to be capable of any good produce of vegetation; but if, when the top waters are run off, and the whole surface reduced to the level of the present natural banks of the river and aqueducts, a discharge is provided, that now cannot run for want of level or fall, a very moderate discharge (that would signify but little in respect to the running off of the top waters) continuing to operate by itself separately and independently of the river Witham, and appropriated wholly to the discharge of such internal waters as are left behind, after the flood waters are reduced within their natural banks; I say, such internal dead waters would very speedily be discharged when all communication with the living waters were cut off, though this new and separate discharge was not above half as much as the current of the river Witham in dry seasons.

It is obvious, that a mere removal of Lincoln Lock's staunch would not fully effect this business, even though Brayford Head was fully cleared, and the channel deepened through Lincoln; because, still the Witham water would be obliged to pass through the same channel; that is, it would pass through the preferable channel, in point of fall, while in common, and, therefore, would interfere with, and over-ride the drainage waters at the very pinch when the drainage was wanted to be completed.

Furthermore, if the Fossdyke navigation was supplied with water by an aqueduct from a higher part of the river Witham, independent of Brayford Meer, and the outlets of all such grounds as drain into Fossdyke east of Saxelby, or into Brayford Meer, banked off (making Fossdyke itself a means of discharging the top waters

when the whole country is over-pressed), then Brayford Meer may remain at its present height, and all impediments be removed between Brayford Meer and the first lock towards Boston, as low as to the floor of the water-way under Lincoln High Bridge, which would render the navigation through Lincoln much preferable to what it now is, as there would be 2 feet depth of water at such times and places where now there is no more than one.

THE SCHEME.

1st. To remove the lock, called Lincoln Lock, and its staunch, from its present place below Stamp End, to above the tail of Sincil Dyke, where there is a commodious opening to receive it, as will appear from a sketch of the manner in which it may be placed.

2d. To deepen that part of the river Witham that lies between the present place of the staunch, and the place where it is now recommended, so as to make it passable for any boats that can now come up to Lincoln Lock, and which will not require a deepening of above half a foot at a medium.

3d. To scour out Sincil Dyke to as great a width as it has ever originally been, from its tail or out-fall into the Witham, to the tail of the great Gowt Drain, bringing up its bottom upon the same dead level with the bottom prescribed in the last article, as necessary for navigation, and to as great a width as it will carry, after allowance of sufficient slopes.

4th. To dyke and scour out the great Gowt Drain to the greatest width it will bear, and still bring up the bottom upon the same dead level as prescribed for Sincil Dyke; but, instead of opening a communication with the river Witham, to continue the said drain under the river by means of an under-ground tunnel 4 feet wide and 4 feet high clear water-way, with doors pointed towards Sincil Dyke. The floor of this tunnel to be laid so much deeper than the bottom of the Great Gowt Drain, that the river Witham may run in its present natural course above its arch, and that the work of the said arch be finished as high as that the river Witham may pass over it without raising its surface, in its ordinary or extraordinary state, upon a width of at least 30 feet. The west side wall next the low lands to be raised to a competent height to prevent the Witham's waters, in time of floods, from cascading over it; but the height of the east wall to be raised only one foot above the ordinary surface of the Witham, so that, when there is a swell in the Witham above that height, it may cascade over into this Gowt Drain, which will then act as a slaker, according to its present intent, and make its way by Sincil Dyke to the Witham.

5th. To scour out Sincil Dyke, from the tail of the Great Gowt Drain, to its upper mouth at the river Witham, yet not to make an open communication with the river; but to prevent the river in dry times from taking its course that way, and to give it a competent passage through Sincil Dyke as a slaker drain (to which use it has been apparently intended in its original formation), to construct a weir of 60 feet in length upon the crown, ranged along the east side of the river Witham, which, being immediately collected into Sincil Dyke Drain, can run no more water in high floods than the drain will and ought to contain: in time of dry seasons to be about one inch above the water's surface of the river, so as just to pen in all the water

thereof, and, upon a fresh rising above that, to discharge a competent quantity, upon a moderate additional height, in virtue of the length of its crown.

6th. To effectually scour out the lesser Gowt Drain, and, in like manner as the entry into Sincil Dyke, to be shut off by a weir of 45 feet long in the crown, conditioned and operating as Sincil Dyke in proportion to its size: but to allow for the natural fall of the river from Sincil Dyke to the entry of the little Gowt Drain; this weir to be gauged $1\frac{1}{2}$ inch lower than the former. And, N. B., it will be proper to give all possible freedom and effect to these 2 slaker drains, because the Great Gowt Drain will not now serve this purpose except in floods.

7th. A drain to be carried from the said tunnel, at the head of the Great Gowt Drain, to Swan Pool, and to pass by or through the same, as shall be found most convenient and practicable in the execution; to be of 12 feet bottom, with proper slopes, and still carried on upon the same dead level. From thence the drain to pass forward upon a 10 feet bottom to a proper place, to divide into two branches; one tending towards Cuckoo Pool, and the interior parts of Skellingthorpe; the other towards a proper point of the Fossdyke, to receive the Burton and Carlton, &c. waters, from Bishop's Bridge, by a subterraneous tunnel under the Fossdyke; all which said drains are to be carried on upon the same dead level as before prescribed.

8th. A subterraneous tunnel to be laid under the Fossdyke, to communicate the water from Bishop's Bridge, of sufficient capacity to run the drainage waters without material loss of fall after the top waters are discharged; but, as the laying a tunnel of this kind, the top of whose arch must be so deep below the common surface of Fossdyke as to clear the navigation, the construction of such a tunnel by the ordinary means in brickwork would require so much length of time as to be a great loss of tolls to the navigation, which, together with the actual expense, would lay too great a burden upon the scheme I am proposing: I would, therefore, recommend the tunnel under the bottom of the navigable river to be made of cast iron. This to be made in proper lengths with flanches, by which they can with bolts be readily joined together; and I expect that a clear iron pipe of 2 feet 6 inches diameter would be very competent to this business, but that of 3 feet would put it beyond all doubt.

9th. From this tunnel a drain should (still upon the same dead level bottom) be carried to Bishop's Bridge, and that bridge rebuilt correspondent to such depth, the width of the drain's bottom to be 9 feet, and the tunnel of the bridge correspondent; from thence the drain to be carried forward, as a private work, into Burton and Carlton lordships; but still I would recommend, that whatever width may be taken for the bottom, that it be carried on upon the same dead level till it comes to the pinch of that drainage, which, according to Mr. GRUNDY, is in South Carlton lordship, and that the ground in the lowest slade there is no more than $14\frac{8}{10}$ inches above Brayford Head, as in the year 1762, that is $8\frac{8}{10}$ inches above Brayford Meer, as I found it this year, 1782; from thence the main drains, as well as side drains bottoms, may be allowed to rise at discretion.

10th. I would recommend a drain to be continued from the former, at or near Cuckoo Pool, through Skellingthorpe, by way of the low slade of the ancient course of the Till, into Saxelby Pasture, till opposite Saxelby Meadow, on the north side of the Fossdyke, diminishing from a 7 feet bottom at Cuckoo Pool, to a 5 feet bottom at the said point in Saxelby Pasture; but still continuing the same dead level.

11th. Between Mr. Ellison's wharf and Brayford Meer to construct a navigation lock, with gates pointed towards the Fossdyke, shutting up all other communication between Fossdyke and Brayford Meer, except by a weir, as per next article.

12th. To make an aqueduct of 10 feet bottom, to take its water at the river

Witham, just above the Great Gowt drainage-tunnel, and to pass to the Fossdyke at some convenient place opposite to or west of Mr. Ellison's wharf, in order to supply the Fossdyke with water; and, at a certain height, a weir or over-fall to be constructed, that all redundant water, beyond the supply of the Fossdyke navigation, may be returned into Brayford Meer, and so go to Boston; this ought to be 40 feet in length upon the crown.

N. B. This aqueduct necessarily intersecting the drain prescribed in the 9th Article, is to pass it, by a continuation of the tunnel, as an aqueduct bridge, to convey its water in a separate passage over the drain, and to be well embanked on each side, so that it be never overflowed till the country is under water.

13th. To make a provisionary navigable staunch at Brayford Head, the gates whereof to be gauged to the same height that Brayford Head was in 1762, that the navigation into and upon Brayford Meer may not be dependent upon the staunch at Lincoln Lock, and the whole passage cleared from Brayford Meer to Lincoln High Bridge, as deep as the floor of the passage of the said bridge; and, then, if the trustees for the navigation from Boston to Lincoln think proper, in like manner, to clear away to the same depth east of the said bridge, there will be a clear navigation from Brayford Meer to the sea, equivalent in all parts passing Lincoln to that under Lincoln High Bridge.

N. B. In time of floods the gates of the Brayford Head staunch must be set open, as well as the doors of the Lincoln Lock staunch, for relief of the country west of Lincoln, in running off their top waters, as I am informed is very properly the present practice; but it should seem that the opening and shutting of these doors should be within the direction of the Magistrates of the city of Lincoln, who, being most central, will more readily be apprised of, and see the necessity of the country.

14th. That, for the general relief of the country west of Lincoln, and the more speedily to get rid of their top waters, which, as before, will continue to overflow the whole country in the winter season, it will be very proper to embrace Mr. Ellison's proposition of granting liberty for a side weir to be constructed of a proper height at Torksey; so that a part of the top waters may be run that way into the Trent, when the level of the Trent will admit thereof, as it often at such times does. This weir, however, should not be too low, that the Witham fens drainers may have no reasonable complaint of losing water to keep their out-fall clear; nor should it be too high, because, if so, it will be of little use in answering the purpose for which it is made; but it should be of considerable extent in length upon the crown, that when it does discharge, it may do it with effect. It appears to me, that if it is made 100 feet upon the crown, its height 6 inches below the gauge bar of Torksey Lock, that is about 4½ inches higher than the framed bar, it will answer all these purposes. This would be easily constructed, extending 100 feet eastward from the east end of the wharf wall, on the south side of Fossdyke: but, as its discharge cannot be permitted to over-ride the Fenton Drain, the present south bank of the Fossdyke must be carried forward from the east end of the weir, between the weir's water and the Fenton Drain, quite up to the walls of Torksey Bridge; and to be made proof, so that the water shall never, after passing the weir, flow into the drain: and, furthermore, as the Trent floods frequently greatly over-ride the Fossdyke waters, even in their highest condition, it will be necessary that the water of this weir should be conveyed to Trent by a separate passage, intermediate between the lock and Fenton Drain, whose outlet must be shut by doors pointed towards the Trent. A proper capacity for this passage will be about 8 feet wide, and 5 feet high in the clear; but

its threshold need not be laid so low as that of Fenton Drain by a foot, so that as the foundations may be completely in the dry, it will not be so expensive as sluice-work often turns out to be.

15th. The living waters of the Till can evidently have no other out-fall than into the Fossdyke. The Fossdyke will be, by the proposed mode of supplying it with water from the Witham, held about 10 inches higher in very dry seasons than it formerly was; but if the Till, which has now little or no banks, was embanked 10 inches, it would at all times be as competent to hold in the living waters as now, before the adjacent meadows were overflowed. But, let us suppose it embanked 2 feet, yet, as the ground is low on both sides, but the lowest in Saxelby Meadow near Haddow Bridge, which then would not be more than 2 inches above that advanced height of the surface of the Fossdyke, this would necessarily be too small an elevation of surface for these grounds ever to have a competent drainage; but, as they are but of small extent, when the living waters of the Till are so embanked from them, a very small tunnel, with a competent fall, would effectually drain them; for this purpose, I would propose to drain them by means of a leaden pipe of 5 inches bore, under the Fossdyke, into the drain proposed to be carried on the south side to Saxelby Pasture, laying also a small common tunnel under the Till, to communicate a few acres of drainage from Haddow Meadows (which are the higher) into Saxelby. I prefer, in this case, a leaden pipe, because it may be lowered into the water, and completed, without ever interfering with the navigation at all. Or, if better approved, these meadows near Haddow Bridge may drain by a communication across the Till as aforesaid (but from Saxelby into Haddow), and then by way of South Carlton to the great iron tunnel proposed in Article 8.

OPERATION OF THE PRECEDING SCHEME.

Upon my late view I found the pen of Lincoln Lock to be good 14½ inches, with a competent fall for the current waters of the Witham through Lincoln and the Slaker drains, which I estimate at 1½ inch more; that is, in the whole, good 16 inches: it is, therefore, manifest, that by the means proposed these 16 inches will be added to the natural fall of the drainage-waters that they now have into Brayford Meer; and the living waters of the Witham will then get discharged as they do now, and the internal drains, being carried upon dead level bottoms, and dug below level till they get to the pinch of their respective services, will perform their drainage down to the dead level of their outfall, in which case the point in South Carlton, that is reported to have had but 1 foot 2¼ inches elevation above Brayford Head, as it was in 1762, that is, but 8¼ above the level of Brayford Meer, as I found it the 31st of August last, will then have a fall of 2 feet ¼ inch from the said surface to its out-fall; and the low slade in the west of Skellingthorpe, that was the same day 6 inches above Fossdyke (that is above Brayford Meer), will have a fall of 1 foot 10½ inches to its out-fall, which will fully suffice for a perfect drainage in seasons moderately dry; but, this being somewhat less than what has been esteemed complete, I must beg leave in this place to take notice, that formerly, when it was not the practice to dig drains below the dead level of the out-fall, nor to carry their bottoms upon a dead level, but rising towards the country to be drained, it was then held necessary to have a calculation that the utmost reduction of the water within

soil should not be less than 2 feet. But the experience of the last 20 years has informed me, that where measures are taken to make the drains readily and speedily (after the top waters are discharged) reduce their water's surface 1 foot within soil where it is tolerably firm, will form a very effectual drainage, and in soils less firm 18 inches done speedily will be full as effectual as an ultimate of 2 feet performed in that slow lingering manner which is the consequence of shallow drains, containing no competent body of water in the bottom, to be moved; for let the body be however great, gravity acting with equal force on every particle, the fall being the same, will give every particle an equal velocity, and consequently the whole. Now, as I found Saxelby Meadow was elevated above Fossdyke 11 inches, it will, by what is proposed, be elevated 2 feet 3 inches above its out-fall, and, therefore, several inches to spare to give its water a competent velocity through the pipe.

Hence, it is evident that the drainage of all the low grounds will be completed in all summer seasons, but will, as at present, be subject to be overflowed by the great winter's floods, but whose top waters will be more speedily run off by the discharge into Trent, and by the drainage waters running off with a good current, when at present they do not run at all.

By avoiding all embankments of the Witham, and the waters allowed to spread as at present, all oppression of the drainage lands east of Lincoln is avoided; and in running off their ultimate drainage waters of the west country more speedily, the east country will be greatly benefited, because they will be sooner ridded of their western waters coming upon them; for this must be laid down as a rule, that, in like circumstances, the lands downward upon a stream can never expect to drain prior to those above them, and, therefore, the sooner the waters of those above are discharged, the sooner the drainage of the whole will be completed.

The navigation east of Lincoln High Bridge will be greatly benefited, because Brayford Head being cleared away down to the level of the floor of Lincoln High Bridge, will give 1 foot more water than at present, and the like advantage would take place quite through Lincoln, if the Witham, east of the said bridge, was suitably cleared.

The Boston out-fall will also receive benefit, notwithstanding that some of the top waters will be discharged into the Trent, because it can be no advantage to a country already oppressed with water to receive an addition; and as the follow of the living waters will be continued in a more full body after the extremes are gone, the powers of scouring will be continued to a period, when otherwise they would have ceased.

In order to state the advantage to the Fossdyke navigation, and its relation to the drainage of the country, it will be necessary to ascertain some fixed points of level.

In the year 1762, it was ascertained by Mr. GRUNDY and myself, that when there was 4¼ inches depth of water over Brayford Head, the surface was then 5¼ below the top of the Aisler course of the Lincoln stone in the face of Mr. Ellison's wharf, consequently, the said course was at that time 10 inches above the natural stanch of Brayford Head.

On reviewing the same in the year 1782, I found 1 foot water upon Brayford Head (as held up by the stanch of Lincoln Lock below), and at that time its surface was 4 inches below the said Aisler course, consequently the Aisler course 16 inches above Brayford Head, as it now is; that is, Brayford Head, in 1782, was lower, by 6 inches, than in the year 1762, and the surface of the water of Brayford Meer was 1¼ higher. I would, therefore, recommend that the crown of the proposed

weir to pen the water in Fossdyke, and over which the surplusage shall fall into Brayford Meer, to be 5 inches higher than the said Aisler course, which, in fact, will be all that will be gained to the Fossdyke; because it is said, and I suppose may be proved by evidence, that when this wharf was built, about 40 years ago, the said Aisler course was completely covered with water, that stone being of the reputed quality not to bear the weather. The crown of this over-fall being about 11 inches lower than the proposed weir at Torksey, will, therefore, be the gauge height of the Fossdyke navigation, whenever the flood waters do not raise the whole country above that level; and whenever that is the case, it will be proper to open the gates of the new proposed lock joining Brayford Meer, to let the flood waters of the Till have a free vend, so as not to be unnecessarily accumulated upon these lands, that necessarily drain into the Fossdyke.

I come now to prove, lastly, that the whole of those lands, that necessarily drain into Fossdyke, will be benefited by the alterations proposed; because, as those all lay westward of Saxelby, the discharge by the weir at Torksey will have the greatest and quickest effect upon them in running off their top waters the most speedily; and respecting their ultimate drainage, it is manifest, that whenever the waters of the whole country is above the proposed gauge height of Fossdyke, that it will be the same thing to them, whether the over-fall at Brayford is in being or not; if, therefore, when at or under that height, all these lands have all the ultimate drainage they have now, or can have, they can be no losers in that article.

The only drain into Fossdyke, that has the appearance of being in the least likely to be affected by the proposed advancement of the surface of the Fossdyke, is Thorney Drain; I mean that with a pair of doors at Drinsey Nook. Of the circumstances of this drain I took particular notice, and must infer, that in point of ultimate drainage it fully does its business; because if it did not, as I found the water of Fossdyke just covering the threshold, and a rise of the pavement or floor, from the threshold of the door towards the land, of between 9 and 10 inches, I conclude, if this drain did not, in its present circumstances, do its duty, this rise in the pavement, which operates as a dam, being taken away, and the bottom of the drain lowered correspondent thereto, it would be enabled to have run off the water lower by all this difference. I took a very careful level between the surface of the water of Fossdyke as it then was, and the top of this stone pavement, and found that the rise was 9¼ inches in the compass of 3 yards. The water being then 4 inches below the Aisler course at Mr. Ellison's wharf, if raised 5 inches above it, this would make 9 inches; that is, the surface of Fossdyke would be still a quarter of an inch below the paving, and, if even with the top, would be no impediment to any water flowing over it, for water could not flow over it without having some thickness, or depth upon it; and if it was 2 inches deep, it would have an immediate fall of 2 inches into Fossdyke, by which it would be delivered as fully, freely, and uninterruptedly, as if it had a pit to fall into from the top of the pavement, of 100 yards deep; and, in fact, as the drain's bottom (which I pursued about half a mile) seemed to lay nearly on a level with the top of the paved floor above mentioned, and was greatly trod and poached by the feet of cattle that made their passage along it, to eat the grass upon its sides, the condition of it is such, that if the Fossdyke, instead of being raised 9 inches above the level it then had, was raised 15 inches, I would engage, if necessary, to make it run off its water lower at half a mile distance after that, by digging it as deep as the threshold of the sluice, than it can do at its present depth and condition, though the Fossdyke was totally emptied of water. It will, therefore, clearly appear, that the difference of an inch or two that may occasionally

be made by the thickness of the sheet of water going over the over-fall at Brayford (or even if it was 6) will make no sensible difference in the effect of the operation of this drain, to which the more quick running off the top waters being the only thing desirable.

Austhorpe, December 31, 1782. J. SMEATON.

PROBABLE ESTIMATES OF THE EXPENSE OF THE ABOVE WORKS.

1*st. For such Works of Drainage as would be necesary in case the Fossdyke Navigation was to remain in its present State.*

	£.	s.	d.
To removing Lincoln Lock and Stanch above Sincil Dyke, deepening the channel, where necessary, up to the same, and making good the wharfs, say	200	0	0
To scouring out and deepening Sincil Dyke from its tail to the tail of the Great Gowt Drain, and from thence the Great Gowt Drain to the Witham	172	0	0
The contingence of under-pinning the two bridges upon the Great Gowt	20	0	0
To making the subterraneous tunnel under the Witham	150	0	0
To scouring out the Lesser Gowt Drain, and remainder of the Sincil Dyke to the Witham	33	0	0
To weirs at the head of each	30	0	0
To the drain leading from the subterraneous tunnel to the point of departure of the two drains, according to Article 7th, being 400 roods, at 9*s.* 6*d.*	190	0	0
To three lengths of iron pipes, 3 feet diameter, for the grand subterraneous tunnel crossing Fossdyke, weight 5 tons 15 cwt., at 16*l.*	92	0	0
To bolts, jointing and laying	10	0	0
To brickwork at the two ends	20	0	0
To taking off the water and pumping	25	0	0
To continuing the drain from the said point of departure in Skellingthorpe, through the iron tunnel to Bishop's Bridge, being 332 rods, at 8*s.*	133	0	0
To rebuilding Bishop's Bridge	10	0	0
To continuing the drain from the said point into Skellingthorpe, upon a 9 feet bottom, to the point K, being 410 rods, at 8*s.*	164	0	0
To continuing the said drain from the point K to the west boundary of Skellingthorpe, 333 rods, at 6*s.*	100	0	0
£.	1349	0	0
To 10 per cent contingencies upon the above articles	135	0	0
£.	1484	0	0

N.B. As I suppose the trustees of the Boston navigation must be considered as aggressors, the removal of the lock and stanch should be at their expense.

ESTIMATE

of such Works as will be necessary for the Improvement of the Fossdyke Navigation upon the Plan proposed.

	£.	s.	d.	£.	s.	d.
To building a new lock between Fossdyke and Brayford Meer, digging and pumping	500	0	0			
To additional work at the Witham tunnel, to make it serve as an aqueduct bridge over the drain, and to receive a gate for regulating the water	120	0	0			
To cutting the aqueduct from the said tunnel to the Fossdyke, for carrying the water for navigation, being 240 rods, and securely banking the same, at 12*s.*	144	0	0			
To two communication-bridges over the same, if of brick, 20*l.* each	40	0	0			
To making an over-fall from Fossdyke into Brayford Meer of brick or stone	100	0	0			
To making a stanch at Brayford Head	150	0	0			
To deepening and scouring from Brayford Meer to Lincoln High Bridge	25	0	0			
Carried over				1079	0	0

The following Works I look upon as contingent upon the Rise of the Water at Fossdyke.

	£.	s.	d.	£.	s.	d.
Brought over				1079	0	0
To carrying forward a drain for the west bounder of Skellingthorpe through the corner of Saxelby Pasture, and by a leaden pipe across into Saxelby and Haddow Meadows, length 256 rods, at 5*s.*	64	0	0			
The leaden pipe 12 cwt., at 1*l.* 1*s.*	13	0	0			
To solder, labour, laying, and fixing	5	0	0			
To brickwork at each end, with proper grates to shut and hinder it from choking and running at improper times	10	0	0			
To banking upon the Till up to its division, length 88 rods on each side, at 2*s.* 6*d.* per rod	22	0	0			
To a tunnel across the Till, wood and laying	2	0	0			
				116	0	0
				£.1195	0	0
To 10 per cent contingencies upon the above articles				120	0	0
				£.1315	0	0

The making the weir at Torksey, being advantageous, not only to all the lands in question, but to the navigation, by more readily freeing the same from extremes of water, and, also, by quieting the apprehensions that the land-owners might entertain from the rise of the surface of Fossdyke in dry seasons, it seems to me should be done at a joint expense.

	£.	s.	d.
To making the weir, walling, paving, and securing the channel for carrying off the water, embanking between the said channel and Fenton Drain, making the tunnel through the road, and pointing doors towards the Trent, cannot lay at less than	500	0	0
Contingencies upon it at 10 per cent	50	0	0
	£.550	0	0

ABSTRACT.

General drainage scheme	1484	0	0
Fossdyke navigation	1315	0	0
Torksey Weir and accompaniments	550	0	0
Total	£.3349	0	0

Austhorpe, December 31*st*, 1782. J. SMEATON.

HOLDERNESS LEVELS.

Report of JOHN SMEATON, *annexed to a Report and Estimate of Mr.* GRUNDY'S, *concerning the Drainage of Holderness Levels..*

HAVING carefully perused the foregoing observations, and also compared them with my own, taken upon the place, in the month of November last, and finding no difference between them that can any ways affect the practicability of the proposed drainage, or the general scheme to be made use of for that purpose; and having also considered the causes assigned by Mr. GRUNDY for the drowning of this level, and the expedients to be made use of for the remedy of the same, I entirely concur with him in every essential point. But as a number of adverse accidents have prevented us from meeting upon this business, according to the desire of the proprietors, which has prevented our comparing our ideas together; and as men's ideas often vary in particulars though they agree in general and material points; and as I find that some

things have struck me in somewhat a different light to what they have done Mr. GRUNDY, I think it my duty to point out the same, not so much by way of correction of what he has proposed, as by way of supplement.

1st. In regard to the out-fall clough, Marfleet must strike every one, at first sight, as being the most eligible place; and, was there any want of fall, would certainly be so; but as there appears an ample sufficiency of fall into the river Hull at the Sugar-House clough, it being so much above low water in the river Humber, allows it to run so much the longer; and if laid nearer low water mark (without which it could have no preference upon the Humber), it would be more difficult to maintain a channel from the clough to low water mark; and the shore being flat and muddy, and the water ebbing out a great way, the sea-doors would be more liable to be silted up in dry seasons. I can, therefore, hardly tell how to give the preference to Marfleet.

2dly. Was the eastern main drain, instead of going round by Gold Dyke Stock, to be conducted from Old Williams at *b*, through Fordyke, to about the midway between Fordyke Bridge and Fossam Style; and there making an obtuse angle, to meet the eastern drain, about the point *VI.*, and then, to proceed together in a right line to *D*, the course of the main drain would be shortened near upon a mile, which, according to the laws of drainage, is eligible, in case other circumstances of greater weight do not counteract; and, then, the course of the drainage of Sutton Carr, &c., which would be north, would be more natural; for, according to my information, those carrs are deeper about the fillings and Chester Hole, than near Gold Dyke Stock. The lands on the south of Gold Dyke Stock could drain as at present.

3dly. In case any objection is raised by the proprietor of Waghen, now under drainage by engines (which, if this scheme takes place, will be unnecessary), the eastern drain may be brought from the angle between K and L, in Weel Carr, through the main drain, under Mieux Bridge; and turning S. E. near Lamber Coat Bridge, to fall into the eastern drain, in a proper direction, between *b* and *c*; and though this course would be near two miles longer than the eastern one already marked out, and therefore less eligible, yet as there is fall enough, I propose it as a practicable scheme in case of difficulties.

4thly. I apprehend a sluice of less dimensions than 24 feet water-way, would drain these levels, when the banks against the river Hull are made tight and firm; as it seems to me that country clew would be almost sufficient, was it placed where there was a proper fall: however, I would advise nothing less than two tuns of 18 or 20 feet, but dimensions, in this case, if an error, is one on the right side.

5thly. The places of the present cloughs are very proper for tunnels for taking in water from the river in dry seasons; but, as I cannot suppose, after the above works are executed, that they will ever run, I cannot think them worth maintaining in their present form. The present extraordinary inundation, I suppose, to be principally owing to the badness of the banks against the river Hull, which allow a considerable part of its contents to be discharged upon this level.

6thly. In regard to the estimates, the shortness of the time that accidents have allowed me for these remarks, puts it out of my power to enter into them particularly; but well knowing Mr. GRUNDY's correctness and assiduity in those matters, I have only to observe, that, though I think he has allowed a sufficiency of dimensions, I should be glad he would reconsider whether the price allowed for the spade-work will be sufficient also. On this account, I would count the sum of £.10,652, exclusive of the articles of surveying, planning, schemes, estimates, supervising, and other contingencies, and procuring the act.

AUSTHORPE, 12th January, 1764. J. SMEATON.

Examination of Mr. GRUNDY'S Plan for a Sea Sluice for the Drainage of Holderness Levels, by JOHN SMEATON.

THE general design and idea of this sluice I much approve; but as I think it may be made stronger with the same expense, I therefore submit the following remarks to Mr. GRUNDY's consideration.

1st. The sluice pit is directed to be dug 3 feet below low water mark, and the floor to be laid 1 foot below ditto.

	Ft.	In.
Thickness of the mud sells	1	0
The ground sells being let down thereon, I suppose 2 inches will rise	0	10
Thickness of the plank	0	3
The pointings being let into the floor, I suppose 1 inch rises	1	1
Total rise above mud sells pile heads	3	2

Quære, Does Mr. GRUNDY propose letting the mud sells into the bottom 14 inches; if so, it should be more clearly expressed; as I suppose it is the second floor, or top of the threshold, that is to be 1 foot under low water.

2dly. It is proposed to pile the mud sells at every 6 feet, so that every other ground sell will bear hollow upon the mud sell, which I suppose is intended for its principal bearing; and every ground sell, being piled in the intermediate spaces, will have a superior bearing to that where the walls stand: I would, therefore, propose to pile the mud sells under the intersection of every ground sell, and omit the intermediate piles, or do them only with slabs spiked against the ground sells, after laid; but this, in my opinion, is unnecessary; but I would add piles under every ground sell answerable to the faces of the pier, for the length of the part that at present bears hollow, and on one row of piles, at 6 feet distances only; this middle row under the pier, for the arches' length, I would still continue at 6 feet distances. In this way, mud sells of 12 × 6 will do as well as 12 × 12, and the timber saved may, if thought necessary, be employed in slab piling the intermediate spaces.

3rdly. The projection of the floor beyond the walls, I think not only an useless expense, but prejudicial in effect, because the back side of the wall bears hollow, and not immediately upon the pile heads; it is true, a wall of this sort is not inclined to fall backwards, but if the ground should prove bad, and the wall be inclined to settle, (for which cause only piles seem necessary behind the front) they had better be applied directly underneath; and if the two outside mud sells, answerable to the back of the walls, are piled at 6 feet distances only, I think it sufficient.

4thly. The row of dovetailed piles under the points of the projection of the pier, I think may be safely omitted, unless the ground is very bad indeed.

5thly. If 9 inch spikes are intended for the 5 inch plank piling, they will reach only 4 inches into the wood; I have, therefore, supposed them, in the estimate, to be of 11 inches.

6thly. Out of the timber supposed to be saved as above, I would lay an additional ground sell close to the other, directly under the points of the pointings, that the jagged bolts may there have something else besides the plank to hang by; but to discontinue them upon the mud sells in the face of the walls: the three ground sells and plank piles to be all bolted together. This last ground sell I would support by 4 piles, correspondent to those marked *d d d d.*

7thly. I think 1 foot rise at the threshold very sufficient, and the second floor plank may be of two inches, or the second beams of 12 × 9. The 20 inch bolts proposed for the 14 inch pointings, leaves but 6 inches to go into the wood below, of which 2 inches is plank; they should be two feet at least.

8thly. It would considerably strengthen the pointings to put a brace or stretcher of an equal height with themselves, cross the pier, according to the direction of the dovetail piles; so that the string pieces, these braces, and the head of the threshold, would all mitre together; and in like manner to fix on a piece jump against the outside heels, to reach about 6 feet into the wall, and to be bolted on with two jagged bolts, each the same as the pointings are fixed by, for which there is provision in the estimate.

9thly. If the lime rubble is mixed with a little quick lime, it will swell and become quite compact, which method I have used in fillings; and the second floor I think had better be filled with solid brickwork.

10thly. The projecting pier I think had better be no longer than sufficient to fasten the studs, as the water will thereby more readily act behind, and shut the doors.

11th. In regard to the plan of the walls, I think a 5 feet base, the length of the arches in this light, unnecessary; that as the arches will ever prevent the external pressure of the earth from driving them inwards, a wall of 4 feet base and 3 feet at the springers will be sufficient; but considered as an abutment to the arches, independent of the weight of earth to be rammed behind, I think it insufficient for a height of 12 feet; in this light the base had better be 7 feet, and 3 feet at top; the contre forts will undoubtedly support the extremities of the arches, but a 15 feet hollow bearing, where there is any dependence, I think is too great in brickwork or masonry.

12th. A base of 4½ feet for the wing walls, is certainly too little for a wall that is to rise at a mean 22 feet, without the help of land ties, or cross beams; and as I am very averse to those expedients, I would propose to make the base of the wings, at the set-on to the body, 9 feet thick; 6 feet thick joining the returns, and 6 feet for the returns; and to make regular sets-off on the back side, so as to be every where 2 feet at top; this will reduce the walls to full as small a size as is supposed at the height of 12 feet; so that the only addition will be 1 foot 6 inches mean thickness upon 12 feet high in the wings, and 1 foot thickness to ditto height in the returns, which, with the contre forts in the wings and returns, will make about 7½ rods of brickwork; which at 6*l.* per rod comes to 45*l.* to do it durably and lasting, whereas with land ties and beams it comes to 57*l.* 8*s.* No addition of expense in the floor will be required, or alteration, save that I would conform it to this figure; and it will be necessary to lay in, instead of common planking, rib-bands, or whole pieces of 6 inches thick, in the face of the wing walls, to hinder their sliding upon the floor.

13th. As the upper pointing is difficult to be supported, from the pressure of the water downwards, I have proposed in the estimate to suspend them by iron loops and stays, to the key-stones of the arches, and plank them flat upon the top.

14th. I apprehend Mr. GRUNDY has, in the height of his doors, had a view to the passages being navigable; otherwise I think, if the doors were only 8 or 9 feet high (which would be fully sufficient for the discharge of the waters) they would be lighter, and therefore move more readily, as well as be in effect stronger.

AUSTHORPE, 13th December, 1764. J. SMEATON.

P.S. It seems to me that there is not occasion to dig the sluice pit to so great a general width as 65 feet: was I to execute it, I should not open the ground to take in more than the extremity of the walls at bottom, and notch in the abutments, returns, &c. in which case the main pit will not be above 50 feet bottom. I have

also altered the position of the sluice pit in the general plan, in order to give it a better direction into the river, which, being in dotted lines, will readily be distinguished.

N.B. I have in the estimate supposed the walls to be carried up 12 feet high, the same thickness as ordered for the base.

ESTIMATE

of Mr. GRUNDY's Plan for a Sea Sluice for the Drainage of Holderness Levels.

CARPENTRY.

	Cubic Ft.	Cubic Ft.
In 84 piles under the mud sells, being 10 inches by 12 head, and 10 feet long, 1 piece of 12 inches square and 10 feet long, make 2 piles, therefore the solid contents		420
In 7 mud sells, 64 feet long, 12 by 12		448
In 96 bearing piles, 10 by 12 head, and 10 feet long		480
1 Grounding to sea sheet piling, 73 feet long, 12 × 12	73	
9 Ditto in the sea apron, mean length 49 feet, 12 × 12	441	
2 Ditto under the sea doors, 62 feet long	124	
5 Ditto under the body of the sluice, 44 feet long	220	
2 Ditto under the land doors, 57 feet long	114	
4 Ditto under the land apron, 45 feet long	180	
1 Ditto to land sheet piling, 62 feet long	62	
In 24 ground ways, 12 × 12	——	1214
In 2 rows of 12 feet dovetail piles under extremity of the sea aprons and sea doors, length 134 feet, there is feet superficial	1608	
In 2 rows of 10 feet ditto, length 106 feet, feet superficial	1060	
Superficial feet of dovetail piles	2668	
Allow $\frac{1}{8}$ for tongueing	334	
Superficial feet, 5 inches thick	3002	
The solid contents thereof is, ... cubic feet	1251	
1 Row of ditto in the extremity of the land apron, 4 inches thick, and being in length 62 feet, and allowing $\frac{1}{6}$ for tongueing, make, in solid contents	207	
Timber in the 5 rows of dovetail piling		1458
3640 Feet superficial of plank in the floor, being 3 inches thick, contains solid		910
6 Ground sells for the second floors under the arches, mean length 21 feet, 12 × 10, solid contents	106	
4 String pieces, 20 feet long, 10 × 6	36	
4 Pointings, 14 × 16, and 7 feet long each	44	
2 Land thresholds, 14 × 16, and 15½ feet long	49	
Plank for the second floor, 3 inches thick, 504 feet superficial, containing solid	126	
Timber in the second floor and thresholds		361
Riga timber in the floor	Cubic feet	5291

	£.	s.	d.
To Riga timber in the floor, 5291 feet solid, at 14*d.*	308	12	10
Allow for waste in converting to the proper scantlings one eighth	38	11	7
To timber in the floor	347	4	5
To preparing and driving 180 piles of 10 feet long, at 2*s.* 6*d.* each pile	22	0	0
To framing, sawing and laying the floor, containing 37 square, at 15*s.*	27	15	0
To 2668 feet superficial of dovetail piling, sawing, making and driving at 4*d.*	44	9	4
Carried over	£.94	4	4

	£.	s.	d.
Brought over	94	4	4
To laying 37 square of planking in the floor, including sawing and caulking, at 7*s.* 6*d.* .	13	17	6
To framing and laying the second floor, containing 5½ square, at 1*l.* 2*s.* 6*d.*	6	3	9
Workmanship in the floor	114	5	7
Timber in ditto	347	4	5
Carpentry in the floor ..... £.	461	10	0

MASONS' AND BRICKLAYERS' WORK.

The external circumference of the walls and pier is 292 feet by 12 feet high, produces 3504 feet of face work, which will be, at a medium, 1 foot 3 inches thick of stone; this produces 4380 cube feet, which, delivered at 1*s.* 6*d.* per foot, comes to	328	10	0
The setting and making mortar for ditto, at 1*d.* per foot	18	5	0
This being supposed to be set 6 inches breadth in tarras mortar, and the hollow posts wholly bedded therein, will take 50 bushels of tarras, at 3*s.* 6*d.*	8	15	0
To extra labour in beating the mortar made therewith, at 1*s.* 6*d.* per bushel	3	15	0
To lime and sand for making the tarras mortar, and bedding the stone work, containing 14 rods, at 9*s.*	6	6	0
Masonry to 12 feet high ..... £.	365	11	0

	Sup. Ft.	Solid Ft.
To stone facings for the wings and returns to 6 feet above the spring of the arches	966	1208
To ditto in the 2 face walls	1088	1360
To ditto in the 4 rampart walls	460	565
	2514	3133

To 3133 cube feet of stone work, at 1*s.* 8*d.* per foot	234	19	6
To setting ditto and making mortar, at 1*d.* per foot	13	1	1
To lime and sand for mortar for ditto, 10 rods, at 9*s.* per rod	4	10	0
Masonry above 12 feet high	252	10	7
Masonry below 12 feet high	365	11	0
Masonry in the face of the walls ..... £.	618	1	7

ESTIMATION OF A ROD OF BRICKWORK.

To 4500 bricks, at 15*s.* per thousand	3	7	6
To 20 bushels of Houghton lime, at 8*d.*	0	13	4
To 40 bushels of clean sand, at 3*d.*	0	10	0
To workmanship	1	8	0
Rod of brickwork	5	18	10
This, in the following estimate, I call	6	0	0
The whole contents in solid, to 12 feet high, is 13,548 cube feet, from which deducting 4380, the cube measure of the masonry, there remains 9168 cube feet of brickwork, making 29·7 rods, at 6*l.*	178	14	0

The brick backing for the wings, and returns to make the whole 3 feet thick at a medium	1690 cube feet.
To ditto for the faces to make the same thickness	1428
To ditto in the rampart walls, to make the whole, at a medium, 2 feet 3 inches thick	420
To cube measure in the arches a brick and half	712
Brickwork completed	4250 cube feet.

The upper works in brick contain 4250 cube feet, which, at 309 feet to the rod of 14 inches thick, contains 13·8 rods, at 6*l.*	82	16	0
Brickwork in the backing and arches ..... £.	261	10	0

CARPENTRY IN THE SEA AND LAND DOORS AND POINTINGS.

A sea door,	Cube Ft.	In.	£.	s.	d.
In 1 turning post, 13 feet long, 9 × 9	7	4			
1 clapping post, 12 feet long, 9 × 9	6	3			
The under rail and upper ditto, 9 × 9	7	11			
4 rails, 28 feet long, 9 × 7½	13	3			
66 feet of 1½ inch plank	8	3			
Solid timber in each door	43	0			
To 43 feet of timber in each door, framing and hanging, at 3*s.* 6*d.* per foot, is 7*l.* 10*s.* 6*d.* each door, and for 4 sea doors			30	2	0
	Cube Ft.				
In the main beam for the pointings, 34 feet long, 12 × 14	40				
The 4 pointings, 28 feet long, 12 × 12	28				
The king pieces, 6 feet long, 12 × 12	6				
The covering with 3 inch plank, 36 feet superficial	9				
To timber and framing in the pointings, at 3*s.* 6*d.*	83				
			14	10	6
Land doors, being 11½ feet wide by 8 feet high, contain 92 feet superficial, and being 4 inches thick	31				
With 4 battens on each side, 2 inches thick, 1 foot broad, and 8 feet long, contain 64 feet superficial	11				
Solid timber in each land door	Feet 42				
To 42 cube feet of timber in each land door, framing and putting in place, at 3*s.* 6*d.* is 7*l.* 7*s.* each, and for 2 doors			14	14	0
Carpentry in the doors and pointings			£.59	6	6

CARPENTRY IN THE BEAMS AND LAND TYES.

	Cube Ft.			
To 4 land tyes in each sea wing, and 2 in each return, sea and land, in all 16, to be 24 feet long, 10 × 6	171			
To 16 cross pieces and ditto string pieces, 3 feet long, 10 × 6	43			
To cube feet in land tyes, at 3*s.*	214	32	2	0
To 32 10-feet piles, 10 × 8 head; timber, making and driving, at 6*s.* each		9	12	0
To 3 beams of Riga fir over the sea, and 1 over the land apron, mean length 33 feet, 12 × 12; 132 feet at 14*d.*		7	14	0
To 16 knee pieces for the same, at 5*s.*		4	0	0
To making, getting into place, and fixing the beams		4	0	0
Carpentry in the beams and land tyes		57	8	0
Ditto in the doors and pointings		59	6	6
Carpentry in the upper works		£.116	14	6

IRON-WORK.

	lbs.			
Tail sheeting 73 feet, 146 of 11-inch spikes	146			
Row in point of pier 47 feet, 94 of 10-inch ditto	73			
Ditto in extremity of land apron 63 feet, 126 of 9-inch ditto	72			
To spikes for the sheet piling at 3½*d.*	291 lbs.	4	4	10½
To 16 bolts for bolting the 2 ground sills and sheet piles, together in the 2 rows under the sea and land doors, weighing 4¾ lbs. each, in all 76 lbs. at 6*d.*		1	18	0
To 2500 8-inch spikes for the floor, weight 10 cwt., at 1*l.* 10*s.* per cwt		15	0	0
Carried over		£.21	2	10½

			£.	s.	d.
Brought over			21	2	10½
To 28 jagged bolts, 2 feet long, and 1¼ inch thick, weight 10 lbs., containing 280 lbs., at 4*d.*			4	13	4
To spikes for the second floor, 1 cwt., at 1*l.* 10*s.*			1	10	0
			27	6	2½
Contingencies thereon			2	13	9½
Iron-Work in the floor			30	0	0
To 4 pair of ⌊'s and 8 ditto of ⊦'s for each sea-door, and for the 4 doors 48 pair, weighing, with their rivets, 14 lb. per pair, in the whole 6 cwt. at 2*l.* 2*s.*			12	12	0
To ½ crown nails for the planking of the gates, ¼ cwt.			0	10	0
	lbs.				
To 4 9-inch hoops for the feet of turning posts, weight 10 lbs. each	40				
To 4 8-inch hoops for tops of ditto, 9 lbs each	36				
To 4 2-inch gudgeons for top of ditto, 20 lbs. each	80				
To 4 loops or staples for fixing ditto, 28 lbs. each	112				
To hoops, loops, and gudgeons, for sea gates	268	at 4½*d.*	5	0	6
To 4 bottom gudgeons and 4 pots of cast iron	112		1	0	0
To 4 screw bolts, 18 inches long, ¾ thick, weight	16				
To 4 ditto of 4 feet long for ditto, weight 7 lbs.	28				
To bolts for the upper pointings, at 6*d.* per lb.	44		1	2	0
To 2 sets of loops and stays for hooking the upper points of the key-stone of the arch, 50 lbs. each, at 4½*d.*			1	17	6
To spikes for the planking of the upper pointings			0	5	0
To rivet nails for the land doors, 100 in each door, ½ inch thick, at 3*d.* each			2	10	0
FOR DRAWING THE LAND DOORS.					
	lbs.				
To 2 claspsand eyes with rivets	64				
To 2 studs with plates for fastening to the wall, 12 lbs. each	24				
To 2 chains 16 feet long, ¾ iron	146				
To 2 studs and 2 loops for fixing ditto	16				
Fixed iron-work for drawing the land doors, at 4½*d.*	250		4	13	9
To a common hand-screw fitted up for drawing the gates			5	0	0
To 50 cramps for the cappings, 2 lbs. each, 100 lbs. at 4*d.*			1	13	4
To 5 pigs of lead to fasten cramps and iron-work, at 16*s.* each			4	0	0
			40	4	1
Contingencies			4	15	11
Iron-work in the upper works			45	0	0
Ditto in the floor			30	0	0
Iron-work in the whole			£. 75	0	0
To 188 cube yards of lime-stone rubbish, mixed with 1 bushel per yard of quick lime, well blended together, and rammed in between the timbers of the floor before it is planked			28	4	0
To ½ a rod of brickwork between the timbers of the second floor, close laid in and filled with mortar			3	0	0
Filling in the floor			31	4	0
ABSTRACT.					
Carpentry in the floor			461	10	0
Masonry in the face of the walls			618	1	7
Brickwork in the backing and arches			261	10	0
Carpentry in the upper works			116	14	6
Iron-works in the whole			75	0	0
Fillings in the floor			31	4	0
Drainage of the water, supervisal, and contingencies			200	0	0
			£. 1764	0	1

BRISTOL BRIDGE.

Questions proposed by Mr. STRATFORD, Engineer, concerning Bristol Bridge; answered by Mr. SMEATON.

"QUÆRE 1st. From the state of the old pillars, and strata below the bed of the river, to the solid red sand rock, will it be prudent, or advisable, to attempt the construction of a new superstructure on such old precarious foundations?"

Having duly considered the several matters stated in the foregoing discourse,* as well as the several plans, elevations, and sections, I am of opinion as follows:—

Answer 1st. As all the old pillars appear to be ill-built and damaged, and not sufficiently deep below the bed of the river, which will always render them subject to further injuries from the action of the water, which appears here to be very considerable, I should think this sufficient to their condemnation, if the circumstances of their being ill-sized, ill-shaped, and ill-placed, were not, in the present case, to be added.

"Quære 2d. From the forementioned account of the freshes, will not any attempt to bar up the bed of the river under the bridge be extremely injudicious, and a measure that will greatly add to the present inconveniences felt at the head of the back?"

Answer. The bars mentioned to be thrown up, both above and below bridge, have, undoubtedly, been formed by the matter removed by the current from between the piers; which removal has been occasioned by the bulk of the pillars too much straightening the water-way, which, increasing the current there, has taken out the matter and increased the depth, thereby nature having, in some measure, relieved herself, by getting in depth what she was debarred from in width: an attempt, therefore, to refill those cavities will either be attempted with the same consequences, and an increase of the bars, or, if the new matter to be added is so heavy and compact as to resist the current, the current must be proportionably increased thereby. I should, therefore, think this expedient, in this place, very unadvisable.

"Quære 3d. The position of the bridge being a matter of moment in bridge-building, will not the changing the present position of the old bridge be a real improvement to the part of Bristol at the head of the back, as it will facilitate the passage of all sorts of vessels through bridge; and may not a reasonable expense to gain that advantage be money judiciously expended for the benefit of the city of Bristol?"

Answer. All bridges ought, as near as possible, to have their piers parallel to the natural current of the water, in the place where they stand; yet a small deviation therefrom, so far as it respects the passage of the water only, is not of great consequence to a work that is otherwise firm and well founded: but, in the present case, with respect to the lying and passage of vessels, the deviation very, unluckily, happens to be the wrong way, and, therefore, in the reconstructing this bridge ought to be rectified. I don't mean, that the piers ought to be out of parallel with the stream, but if they had happened to have deviated as much the contrary way, there probably would have been no need of a change. This ought, however, to be attended to, that at the same time the freshes, floods, and strong ebbs, render the vessels alongside the quay less steady, it may be the means of preserving the face of the quays from

* Meaning Mr. Stratford's description of the situation, condition, &c. of the old pillars, and of the several strata under the bed of the river, &c.

an addition of silt or mud; yet the quantity of alteration proposed, cannot, I think, be attended with any danger from this quarter.

"Question 4th. In case of a three-arched bridge, situated on so rapid a river as at Bristol Bridge, will it not be more eligible to construct the salient angles or becs of the piers with cylindric surfaces of 60 degrees, rather than at an angle of 90 degrees, or rectangular?"

Answer. As the shoulder angles of the piers obstructed the water's passage, and the more so as these angles are less obtuse, in all currents they ought to be rounded off; provided this is done, it is little material what angle is formed at the bec; but no way is more advantageous than cylindric surfaces of 60 degrees, which is, at present, the practice of most foreign engineers.

"Question 5th. The first design, a single-arched bridge; the cord at low water mark, 150 feet; the plumb or perpendicular, 32½ feet; the springers of the arch to be carried down, and sunk into the solid red sand rock, according to the plan referred to. Will there be any sort of danger or hazard in executing a work of this large span, under a supposition, that the springers of the arches are carried down to the solid rock?

"N.B. The stone designed for the bridge is a sand stone, which rises soft in the quarry, but immediately hardens in the open air to an amazing firm texture, at the same time the stone can be raised in blocks of any size: I propose one sort of arch stones of 6½ feet long, and 3 feet in the suffit or thickness, and from 3 to 4 wide; the second set, 4 feet 3 inches long, 4 or 5 feet wide, and of the former thickness; the counter arch to bond in with the principal arch, according to the section referred to. The stone designed for the counter arch is excellent, being 4, 5, or 6 inches thick, very wide and long.

"The lime for the mortar of the bridge is of an admirable nature; one sort will set and cement under water, equal with Dutch terras; and the other will also set and cement the stonework together, as if formed of one solid mass.

"This arch from the springers contains 125 degrees of a circle, consequently is 5 degrees above ⅔ of a semicircle, which PALLADIO recommends in all his bridges. As this arch is to be founded upon the solid rock, this arch may be looked upon as semicircular, as the rock may evidently be supposed the part of the arch deficient of a semicircle. A great advantage in a scheme arch, built on a solid rock, is, that the less number of degrees the arch contains, the stronger the arch will be."

Answer. I look upon it that no limit to the span of arches, in proportion to their rise, has as yet been found, since the widest and flattest arches, that have been attempted, upon right principles, have succeeded as well as the narrowest and highest, provided the abutments are good, and the stone and cement whereof they are composed are of a firm texture, as in the present case they are said to be: and as no abutment can be better than a solid rock, and since the manner of carrying down the arch, and stepping it thereupon according to the section, is quite proper, I see no reason to doubt of success, if built upon the plan now before me.

The Aberthan or Watchet lime, which I suppose is here hinted at, I look upon, from experience, to be the best in the world for works under water.

"Question 6th. The second design I propose to consist of a large central arch, and two side arches. In this design will it not be most advisable to carry down the piers and abutments to the solid rock?"

Answer. Though I apprehend the piers of a bridge might be securely fixed upon any of the strata mentioned, by piling and other timber-work, provided there was no other to come at, yet as a rock is undeniable, I look upon it worthy of a considerable

addition of expense to come at it in a work intended to be lasting: how far it may be practicable in the strata mentioned, to get down to the rock by battardeaux, in the middle of the river, I am somewhat dubious; and though it may be come at by the caissoon method, yet, as I think to interpose a grating or floor of timber between the solid rock and solid masonry, is not quite the thing to be wished for; I should, therefore, prefer the single arch, as having fewer foundations, and those more easy to be fenced off and come at, and should prefer the 150 feet arch to one of lesser span, as the abutments will advance less into the river.

" Question 7th. The third design, proposed by Mr. BRIDGES, where the new piers are to be seated on a coping on the old pillars. But as there are so many real objections to this plan, will it not be the most judicious and advisable step entirely to reject every proposal already offered or to be offered for executing that vague scheme?"

Answer. As to Mr. BRIDGES's plan I can say nothing, as not having seen it; but if the old piers are as represented, I think it quite wrong to make use of it at all, for the reasons in the first answer. This I am sure of, if the bottom is unsound, no coping, or any thing else that can be done, can make them sound. Besides, to leave the old spreading bottoms to project under water much beyond the new shafts, and that in an irregular manner, would be very prejudicial, not only to the passage of the water, but the navigation; I, therefore, must conclude, that if a new superstructure must needs be built upon the old bottom, I think it most advisable to shape the piers, and build the bridge conformable.

The queries answered by J. SMEATON,

AUSTHORPE, November 24, 1762.

RYE HARBOUR.

The Report of JOHN SMEATON upon the Harbour of Rye, in the County of Sussex.

THE harbour of Rye, once so famous and flourishing, lies in the bottom of a bay, terminated by the point of Dungeness on the east, and of Beachy Head on the west, but more immediately by Point Fairlee, which lies almost in the same line, at about the distance of 5 miles. This harbour, according to tradition, was formerly very large, capacious, and deep, so that many large ships might lie therein, sheltered from all winds, at anchor at low water. In this state the sea waters every tide overflowed a very large tract of country (now converted into marshes), the influx and reflux of which waters from and to the sea produced so great a power of cleansing and opening, as to maintain itself a channel wide and deep enough for the above beneficial purposes.

Now, as the whole of the waters so flowing in and out each tide must pass through the mouth of the harbour, the action thereabouts would be the strongest of all, and in proportion weak towards the remote extremities: the mud, therefore, and impurities brought in by the sea, and soil brought down by the rains from the high country, would first of all be lodged at those extremities, which, gathering by degrees, in proportion lessen the capacity of the reservoir, which of consequence weakens the influx and efflux, and thereby increases the tendency to silt, or, as it is here called, to swerve up; and those surfaces so overflowed, being by degrees raised out of the reach of common neap tides, begin to gather a surface of grass, which tempting the husbandman to enclose with banks, he thereby shuts out the sea totally, and in consequence

weakens the cleansing power more suddenly than would happen in a state of nature; so that in time the whole of such an inlet will be silted or swerved up, unless a sufficient quantity of land or flood waters have their passage through the same to sea; and the channel remaining at last will be in proportion to the quantity and rapidity of these flood waters. This is the natural tendency of every creek or harbour upon the sea, but differing greatly in degree as situations and quantity of fresh waters from the land, and the impurity of the land or sea water, differ in one place from another.

It appears further, that an immense quantity of flint, pebbles, or broken flints, rounded by the action of the sea, commonly called shingle or beach, and which have either proceeded from the chalk cliffs on the coast, or have been washed up from the bottom of the sea, are produced to the westward of this harbour, and being driven on the shore, which runs in a general direction nearly W. S. W. and E. N. E. the wind at any point between S. and S. W, causes the sea to strike the shore in an oblique direction, and not only to heap up the beach upon the coast, but to drive it along the shore to E. N. E. into the bottom of the bay; that is, into the mouth of the harbour, from whence there is no possibility of return by a contrary action, because all winds from E. to S. E. which should produce that effect, are in a great measure land-locked, and not only so, but are generally less continued and violent than the South-Westerly. Hence then, it appears, that two powers of nature are together combined to produce the destruction of this harbour, viz. the silting within, and the action of the winds and sea without, upon the shingle, to block up its mouth; nor could this last be possibly avoided, in a very little time, was it not for the action of the land waters, which will always maintain themselves a passage to sea (while they have no other), and, though considerable in the winter season, are yet very inadequate to the keeping open such an arm of the sea as this has formerly been, or even now is. The quantity of beach or shingle that has thus gathered at the bottom of this bay and mouth of the old harbour makes a surface of several hundred acres, the position of which in some measure appears by the plan hereto annexed, and is at present in an increasing state; for, as I am informed, that which at present is called the outermost west point has been formed within these ten years; and that which is now called the innermost was then called the outermost; and the point marked B in the plan was then called the innermost, which is conformable to a plan made in the year 1738. Hence, it appears, that a succession of points have formed themselves to the westward of the harbour's mouth, every one leaving a more narrow passage than the former, the present opening between the present points not being above 100 yards wide. There also appears to be a body of beach, marked in the plan A, which is driving down from the westward, in all probability, and will form a point without the present, leaving a passage still narrower. From this view it appears, that the old harbour has been subject to great mutation, and is likely to be subject to still more; and all for the worse: and all able artists who have surveyed the same, have agreed, that nothing to purpose can be done towards restoring the old harbour, or maintaining the same in any tolerable state. In this condition it appeared upon a survey in 1698, by two Commissioners of the Navy and two Elder Brethren of the Trinity House, by order of the Right Hon. the Lords of the Admiralty, who conclude their Report with saying, "And, therefore, we take this harbour to be almost entirely lost, at least in no condition to be preserved for any purpose of the navigation." Indeed, three gentlemen, who were sent to survey the harbour of Rye, by order of the same board, in the year 1719, after declaring their sensibility of the former utility of this harbour, and the bad condition it was then in, propose a remedy; but as this appears quite inadequate to the object, since that time a new harbour was projected, and in part executed, by the

famous CAPTAIN PERRY, who, after performing several great works in Russia, and effectually stopping the breach in the river Thames at Dagenham, was employed here; and this new harbour has been carried on, with some interruption, from that time to this. Its general design and situation is as follows.

The mouth of the new harbour is situated about two miles to the westward of the old one, where the coast makes nearly a straight line for several miles together, and though altogether formed with beach, yet seems to have had no considerable increase of late years, at least not since this harbour was begun; for though a succession of shingle is moving to the eastward, it does not stay here, but lodges in the bottom of the bay. The coast being hereabout W. S. W., and E. N. E. as before mentioned, the mouth of the harbour points nearly square thereto, that is, to S. S. E or rather S. E. by S. At the foot of the beach, which is about low water mark at neap tides, begins a fine firm sand, regularly inclined towards low water, which at spring tides is about 257 yards from the foot of the beach, and from thence inclines by very regular and gradual soundings, so as to make 20 feet water at low water spring tides, and about 23 feet at ditto neap tides, at above a mile right out from the harbour's mouth, which soundings gradually increase further out, and the whole of the bay is excellent anchoring ground, as I am informed. The tides here, at a common spring tide, rise above low water mark 23 feet, and neap tides about 14, that is, about 17 feet above low water mark spring tides, which are the greatest tides I have met with on this coast. The direction of the tides is nearly along shore, and being some distance (on account of the depth of the bay) from the main channel tide, are very gentle, and are attended with this particular circumstance, that whereas the main channel tide sets at the eastward for some time (in most places three hours) after high water, which occasions a strong current to the eastward, at the time of high water; now, in the bottom of this bay, the time of still water, and that of high water, are both nearly the same, which is a great advantage to ships steering into the harbour's mouth, especially in bad weather; all which circumstances, viz. the great rise of tides, the easiness of the current, and stillness at high water, when vessels chiefly go in and out, must be allowed to be advantages favourable to the construction of a harbour in this place.

With respect to the harbour itself, in its original design, it had two stone pier-heads projecting into the sea, as far as the foot of the beach, their distance 120 feet, which makes the opening of the harbour's mouth; but as the course of the beach was intercepted by the west head, and, in consequence, a body of it collected behind the said head, the west head has lately been advanced further out with timber and stone, so as to overlay the east pier 210 feet, which addition is not only the means of preventing the beach from getting round the head so easily as before, but greatly facilitates the entry of the harbour, especially in the time of heavy seas from the S. W. as I have had an opportunity of being eye-witness of a vessel coming in for shelter under these circumstances.

From the pier-head the width of the harbour enlarges to about 200 feet wide, and is altogether in the form of a canal, which, in my opinion, is preferable to any other for an artificial harbour, on account of the advantages in scouring, where the whole depends thereon.

At the distance of 730 yards, or thereabouts, within the piers, is placed a large navigable stone sluice, and the whole of the canal between the pier-heads and the sluice is formed into the arch of a circle of about 45 degrees; so that no part of the mouth of the harbour can be seen from the sluice, nor any part of the sluice from the mouth of the harbour; in consequence whereof, not only the destruction of the sluice-gates, by the sea rolling in upon them, are prevented, but a space of above 200 yards

of the canal, from the sluice downwards, becomes still water, in time of the greatest seas, at the harbour's mouth, which is particularly convenient for such vessels as come in for shelter, and only wait to take the advantage of better weather, or a favourable wind. At present, the bottom of the channel between the pier-heads is about 6 feet above low water mark at spring tides, and about 3 feet above the sill of the sluice: so that at present there is 17 feet water between the heads at spring tides, and 11 feet at neap tides; but, as the body of beach that served as a dam in the harbour's mouth, to prevent the sea from coming in till the works within were completed, has never been totally removed, and as in its present state a sufficient body of back water cannot be collected for effectually cleansing and keeping open the mouth of the harbour, it cannot be looked upon at present as having the greatest depth of water of which it is capable. I am, therefore, of opinion, when these requisites are provided for by completing the whole scheme, that then the mouth of the harbonr, as well as the internal part up to the sluice, may be kept clear, at least as low as the level of the sill of the gates; in which case the common spring tides will give 20 feet water into the harbour and through the sluice, and neap tides, 14 feet; which latter I apprehend to be sufficient for common built merchants' vessels of 300 tons burden.

The sluice is built of Portland stone, and consists of two openings, one of 40 feet, shut by folding gates pointed to landward; the other, of 30 feet clear water-way, shut by five draw-gates of 6 feet wide each: the use of these gates is to shut in the tides received into the canal above the sluice on tide of flood, into which vessels may then pass, or at high water through the great opening, or repass at high water or on tide of ebb; and gates being afterwards shut, and thereby a body of water penned into the canal above the sluice, serves either to keep vessels therein afloat during the whole time of tide, or being let off at low water by means of the draw-gates, produces a scour for keeping open the harbour below.

The length of the canal above the sluice is half a mile very nearly, and, at a medium, is about 150 feet wide at the water's surface, 70 feet at bottom, and dug down to the level of the sill of the sluice. This canal alone, exclusive of the outer harbour, will take in above 200 sail of vessels, but yet does not contain a sufficient body of water to produce the necessary scours below; and, furthermore, this part of the canal, being liable to silt up by the deposition of mud brought in by the sea, will in a few years be choked up, and rendered entirely useless; the silt being gathered at least 4 feet deep at the head of the canal since July last, when the harbour was opened; what, therefore, is principally wanting to complete what I apprehend to be the original scheme, is to bring the land waters and freshes of three rivers, that now discharge themselves into the old harbour of Rye, through the new harbour, by which means the whole will be kept clear, as appears to me, for the following reasons.

The river Rother, together with the Breade and Tillingham channels, which unite in the old harbour of Rye, are said to receive the down-fall and spring waters of above a hundred thousand acres of land; the discharge from whence in rainy seasons must be very considerable. But, without entering into a minute disquisition concerning the quantity of surface, the most certain way of judging appears to me from observation of the size and sort of channel that those rivers respectively are enabled to maintain, so far up as where the silt, brought in by the sea on one hand, and driven out by the land waters on the other, is already come to a balance; and such I take to be the channel of the Rother immediately below Scotch Flat Sluice; the Breade or Winchelsea channel below Winchelsea Sluice; and the Tillingham channel about a mile above the New Bridge at Rye. Now it appears to me, that the Rother and Tillingham waters, united, are sufficient to maintain a channel, from the new canal

to the town of Rye, capable of carrying up vessels of 300 tons; that the Breade channel is capable of maintaining a channel sufficient for ships of 100 tons to Winchelsea Sluice; and that the three together are capable of preserving an open channel through the present canal and new harbour, so as to make at least 14 feet water at neap tides, as above mentioned; and that the necessary widening these channels, for the purpose of discharge of land waters and navigation, will also furnish a sufficiency of reservoir for taking in the tide for the purpose of scours in dry seasons, when those rivers do not afford a sufficiency of water for that purpose; and as this part of the scheme is still to execute, I would recommend it to be done upon the following general principles.

1st, then, I am of opinion, that the present clear water-way at the sluice of 70 feet, is sufficient for taking in as much tide-water as is necessary for the purpose of scouring the outward harbour, and for filling a channel sufficient for navigation to the towns of Rye and Winchelsea, and for bringing down and discharging the land waters.

2d. I am of opinion, that a greater capacity than is necessary for the purposes above mentioned is hurtful, as a channel too wide will be maintained from silting with greater difficulty; and the taking in too great a body of water will bring in a greater quantity of silt, and will occasion an unnecessary fall of water at the sluice, too great for the quiet passage of vessels; and that the tide falling without, before the internal parts are full to the same level, will occasion a diminution of depth of water for the vessels from the sluice upwards. I would, therefore, propose, that the channel of Winchelsea, from the upper end of the new canal to the town of Rye, be widened, deepened, and straightened, so as to be 50 feet wide in the botton; each side to batter at the rate of 2 feet horizontal to 1 foot in depth; the bottom to be so disposed, as to make a part of a plane regularly inclined from the lower end of Scotch Flat Sluice upon the Rother, to the sill of the great sluice: in which case, as the low sill of Scotch Flat lies about $5\frac{1}{2}$ feet higher than the sill of the great sluice, the bottom of the new channel joining upon the new canal at C will be 7 inches higher, and the other end of the new channel D at Rye will be 2 feet 10 inches higher than the sill of the great sluice at the point D; the banks or walls of this canal to be set at least 40 feet from the brink thereof, and to be raised to 25 feet above the sill of the great sluice, to be 6 feet top, to batter 3 to 1 towards the canal, and 1 to 1 landwards.

3d. From the point D to make a cut to the north of the town of Rye, to fall into the river Rother at some convenient point, suppose E; this cut to be 40 feet bottom, to agree with the inclined plane aforesaid, its sides to have the same batters as the former, and its banks or walls to be raised to the same height, to have the same dimensions at top, the same batters and distance as before described, as far as the crossing of the turnpike road F.

4th. To fix a dam across the river Rother, near below the point of diversion E, and to erect a sea wall from the said dam, to some convenient point eastward, upon the present sea wall of the marsh G, and to carry another sea wall from the said dam westward, to abut upon the turnpike road at F, which dam and walls are to be raised to an equal height with the adjoining wall against the marsh, to be 6 feet at top, and to batter both ways, as $2\frac{1}{2}$ to 1.

5th. As a bridge will be wanted upon the turnpike road, before mentioned at F, for crossing the canal, I would propose it to consist of 3 arches, one of 13 feet 6 inches wide, the others of 12 feet each; the large opening to be furnished with two pairs of folding gates, pointed to seaward, and 1 pair of ditto pointed to landward; the sills of these gates to be laid even with the proposed bottom of the canal at this

place, that, is, about 2 feet 10 inches above the sill of the great sluice, and about 1 foot 8 inches below the lower sill, and 2 feet 11 inches below the sills of the navigable chamber of Scotch Flat Sluice.

6th. A navigable sluice to be fixed across the Tillingham channel, at some convenient place within half a mile above the bridge at the ferry, suppose at H, of 13 feet 6 inches in the clear, with a pair of gates pointing to seaward, and ditto to landward, with draw shuttles or slakers in the latter, and the walls or banks of the Tillingham channel, from the said sluice downwards, to its junction with the canal before described, to be heightened in such manner, and in such proportion, as is described for the main channel from the new canal to Rye.

7th. A dam to be fixed across the present combined channel of Winchelsea and Tillingham, at or near the present new bridge at Rye, suppose at K, and the road to be carried over the said dam; the top thereof to be made up to the same height as proposed for the aforesaid new channel from the canal to Rye.

8th. The channel of Winchelsea, from the new canal to Winchelsea Sluice, for the purpose of navigation, and also to obtain a sufficient quantity of earth for the necessary strengthening of its walls, to be widened and deepened at the head of the new canal, to 2 feet above the floor of the great sluice, and to be carried upon an inclined plane, so as to agree with the sill of Winchelsea Sluice at that place; the batters of its sides, the height, strength and batters of its walls, to be the same as proposed for the main channel from the new canal to Rye.

9th. That in case the diversion of the land waters shall occasion the out-fall of Wenway Sluice to choke up, then a new channel to be cut, and sluices erected, for the discharge of Wenway's waters, above the proposed dam at E, into the Rother.

10th. That in case of the total choking up of the old harbour's mouth, upon the diversion of the rivers into the new harbour, as is to be expected, then the proprietors of such ground as is to be gained hereby, shall have liberty to sew the same into the new channel, by an out-fall sluice or sluices, to be erected at their own expense, either in the new dam proposed in the 7th Article, to be fixed across the old channel, near the new bridge at Rye, or to erect the said sluice or sluices in any more convenient part of the banks of the new channel adjacent thereto.

11th. That in case it should hereafter appear, for reasons I am at present unacquainted with, to be more eligible to carry the Rother into the Winchelsea channel, on the south of the town of Rye,—this appears also practicable on the same principles; in which case, the sluice proposed at F, should be erected near the place of the proposed dam at K.

OPERATION OF THE FOREGOING CONSTRUCTIONS.

As the tide will be stopped in the respective channels by the sluices already erected, and proposed to be erected, thereon, I find by computation that the whole cavity of the said proposed channels would be filled through the present opening of the great sluice, in the time of a tide, to nearly the same level within as without the great sluice, by a difference or fall no ways prejudicial to navigation through the same.

That the said cavity, containing near five times as much water as the present canal above the sluice, will be sufficient for the scouring of the outward harbour in

dry seasons, as the land freshes in rainy seasons will be sufficient of themselves, according to all appearances. That the navigation for lighters, &c. up the Breade channel, will remain as it now is; and that the navigation of the Tillingham channel will be put upon a similar footing, that is, with an opportunity of penning in so much water by the land doors as shall be sufficient for navigation, consistent with drainage; that the navigation up the Rother will not hereby be interrupted, because it is proposed on tide of flood to take in as much water, above the proposed sluice at F, as will float the vessels to Scotch Flat Sluice: but to shut out the top of the tides, which will in effect complete the drainage of all the present extensive salts included within the cross walls, proposed in Article 3.

That the drainage of the lands by the five waterlings, White Kemp, Guildford, and Wenway Sluices, will be upon a better footing than heretofore, because having little pen upon them from without, the sluices and banks will be subject to less repair, and will admit less sea water in the drains by leakage, soakage, &c. and at low water will have a better discharge, because their out-fall channels will be less liable to silt. The new cut below will, in my opinion, be amply sufficient for all purposes; for though proposed only 40 feet at bottom, yet, according to the proportions given, will be 80 feet at top, at 10 feet depth; whereas the cut above Scotch Flat Sluice does not appear to be above 30 feet at bottom, the sum of all the openings of that sluice being but 26½ feet wide, and yet through this capacity is discharged all the spring and down-fall waters from an extensive flat and upland country. Again, though the sum of the openings of the proposed sluice at F, is proposed only 11 feet wider than that of Scotch Flat, yet as the sills thereof will lie at a medium of 2 feet 3½ inches below those of Scotch Flat, and about 4 feet lower than White Kemp, which is the lowest of the four upon the marsh wall; that before the water issuing at the sluice F, can pen upon the Scotch Flat, or the four other sluices before specified, the capacity of the new sluice, taking width and depth together, will greatly exceed the sum of all the rest put together. I mention those things more particularly, because, for reasons before given, I look upon all unnecessary widths, either in the sluices or drains, to be hurtful, it being to no purpose to dig out canals merely for the sea silt to fill up again.

I must also here mention another advantage to the drainage of the lands dependent on the sluices before mentioned, and that is, the danger of the loss of their present out-fall; for though the land waters will always find a way to sea, yet it does not follow that it must be at such a perpendicular height or depth as is consistent with the drainage of the lands; this has actually happened in the course of a few years to the river at Boston in Lincolnshire; whereas the new out-fall proposed will be always capable of maintaining its original goodness. And the same reasoning will hold with respect to all the other levels which sew into the old harbour of Rye.

I am, however, of opinion, that the tides ought never to be shut in by the great sluice so as to pen upon the aprons of any of the sluices for drainage, at a time when any of the levels are under water on occasion of rains or other down-fall.

With respect to the Winchelsea channel, as an out-fall sluice, as before mentioned, has been erected thereon, within the compass of a few years, near the town of Winchelsea, which being very properly placed for stopping of the tides, I am of opinion that nothing further is necessary than to strengthen the walls from the new canal to this sluice, as before mentioned, and to keep this sluice in repair; and that no additional sluice on the main channel, between the aforesaid and the new canal, can be attended with any benefit to drainage, and will be an impediment to navigation up to the town of Winchelsea.

I am further of opinion, that no sluice placed to the east of the town of Rye, by way of taking in the tides into the channels, proposed as aforesaid, from the old harbour, can be of any use, because I expect that the first winter after the diversion of the land waters, the mouth of the old harbour will in a great measure, if not totally, be choked up by the sea.

From my view of the works already undertaken, I find many things not yet completed, particularly about the harbour's mouth, the pier-heads, and the wharfing, proposed to extend from the piers to the great sluice, and many things that have gone into disrepair through length of time since the work was done, and for want of letting the sea into the harbour sooner; but as those matters are capable of rectification, I shall at present take no further notice thereof, than in my estimate of the expense that will attend it. And, upon the whole, I am of opinion, that when what has been and is now proposed, is duly executed, that there may be made and maintained 20 feet water at spring, and 14 feet water at neap tides, from the sea up to the head of the present canal, and a proportionable depth, as before specified, up to the towns of Rye and Winchelsea; and that for vessels, such as those depths of water will suit, will be a safe, useful, and commodious harbour, and therefore advantageous not only to the towns and country adjacent, but to vessels trading through the British channel, and therefore useful to trade in general.

London, February 16th, 1763. J. SMEATON.

AN ESTIMATE

For Completing the Harbour of Rye, according to the Plan and Report of J. Smeaton.

	£.	s.	d.	£.	s.	d.
To raising the east pier-head with stone 5 feet higher than it now is, and coping the same with stone, containing 4589 cube feet, at 3*s.* 6*d.* including cramps, comes to 803*l.* and for repairing the decayed part, fender piles, &c. 197*l.*; in the whole	1000	0	0			
To raising the stone part of the west pier 5 feet high and 4 feet thick, 1080 feet, at 3*s.* 6*d.* 189*l.* and for repairs of fenders	200	0	0			
To completing and making up the additional part of the west pier, between the stone-work and new head, and for fixing a capstan upon the said head for warping out ships	300	0	0			
For repairing and backing up with rough stones the wing, wharfing, extending from the east stone-head into the beach fronting the east	300	0	0			
To expenses in clearing out the harbour's mouth, so as to be 20 feet deep at spring tides	500	0	0			
To 2800 feet running of the wharfing, and securing the banks of the present canal from the present wharfing to the sluice, at 2*l.* per foot	5600	0	0			
To repairs of the wharfing already done	200	0	0			
To securing the aprons of the sluice, above and below, with rubble stone, containing 3500 tons, at 5*s.*	875	0	0			
To making 4 wharf-wings for preventing the wash of the water from getting behind the wings of the sluice, containing 140 feet running, at 2*l.*	280	0	0			
To additional mechanism, in order to make the drain-gates rise with more ease	250	0	0			
To carpenter's and smith's work, in repairing and strengthening the present great gates, so as to make them more lasting	100	0	0			
To capping over the piers of the sluice, with Portland stone, containing 3797 feet, at 3*s.* 6*d.* cramps included	665	0	0			
Carried over £.	10,270	0	0			

	£.	s.	d.	£.	s.	d.
Brought over	10,270	0	0			
To making a timber draw-bridge over the head of the present canal, for communicating the road as it now passes over the dam from Rye to Hastings	1000	0	0			
				11,270	0	0
To digging out the channel from the new canal to Rye, containing 261,653 yards, at 3*d.*	3271	0	0			
To removing the present dam, and making such new ones as will be wanted during the progress of the work, and making up the banks, at least to the height specified in the plan	1408	0	0			
To widening and deepening the Winchelsea channel, and making up the banks, as per scheme, containing 49,573 cube yards, at 2½*d.*	516	0	0			
To cutting a new canal to the north of the town of Rye, from the Tillingham channel, at the point D, to the Rother, at the point E, being 40 feet bottom, 16 deep, and 9 furlongs in length, containing 249,736 cube yards, at 3*d.*	3121	0	0			
To constructing a navigable sluice and bridge upon the aforesaid canal, of 37½ feet clear water-way, at the point F	1800	0	0			
To erecting a timber-bridge across the aforesaid canal for continuing the road from Rye to the ferry	500	0	0			
To making a dam across the Rother below the point E	800	0	0			
To continuing a sea-bank or wall from the dam at E, to marsh-wall at G	65	0	0			
To making a dam across the united channels of Winchelsea and Tillingham, near the new bridge at Rye, at K	800	0	0			
To erecting a navigable sluice upon the Tillingham channel, above the ferry, as at H, and making a cross-bank	500	0	0			
To making a new drain, 95*l.* and out-fall sluice for Wenway Crook water, 105*l.*	200	0	0			
To contingent expences upon the whole	2500	0	0			
				£.26,751	0	0

February, 1763.

J. SMEATON.

SCHEDULE

Proposed to be annexed to the Act for finishing the Harbour of Rye.

Manner how the Harbour is to be finished and completed, subject to alterations, as mentioned in the Act.

THE channel of Winchelsea, from the north end of the new canal to the junction of Tillingham channel near the town of Rye, to be widened, deepened and straightened, so as to be a medium of 50 feet wide in the bottom, each side to batter at the rate of 2 feet horizontal to 1 foot in depth; the bottom to be so disposed as to make a part of a plane regularly inclined, from the lowest sill of Scotch Flat Sluice upon the Rother, as it was in the month of February, 1763, to the sill of the great sluice upon the new harbour; the banks or walls to be set at least 40 feet, at a medium, from the brink, and to be raised 25 feet at least above the sill of the great sluice, to be 6 feet top, to batter 2½ to 1 towards the canal, and 1½ to 1 landward.

To widen, deepen, and straighten, the Tillingham channel from the point aforesaid, so far upwards as shall be necessary to come at a proper place of departure into a new canal, next hereafter mentioned.

To make a new cut or canal to the north of the town of Rye, from some convenient part of the Tillingham channel aforesaid, to some convenient point of the

river Rother, the cut to be 40 feet bottom, to agree with the inclined plane aforesaid; its sides to have the same batters as the former; its banks or walls to be raised to the same height, to have the same dimensions at top, the same batters and distance as before described, as far as the crossing of the present turnpike road which leads from Rye towards London; but if any part of the ground shall not be sufficient to allow the batters, slopes, and distance of the banks, before specified, then the sides of the canals and banks to be wharfed up or otherwise supported, so as to preserve the bottom of the canal of the width before specified, and the banks to be made sufficiently strong to hold in the waters to the same height as before specified.

A bridge to be built upon the same turnpike road for crossing the canal, to consist of three arches, one of 13 feet 6 inches wide, the others, of 12 feet each; the large opening to be furnished with two pairs of gates pointed to seawards, so as to form a navigable lock, and one pair of gates pointed to landward; the other two arches or passages to be furnished each with one pair of folding or falling gates to seaward, and gates to landward. The sills of those gates to be laid even with the proposed bottom of the canal at this place.

To fix a dam across the river Rother, near below the point where its course shall be diverted as aforesaid, and to erect a sea wall or bank from the said dam to some convenient point eastward, upon the present sea wall of the adjoining marshes, and to carry another sea wall from the same dam, westward, to abut upon the aforesaid turnpike road; the said dam and walls to be raised to an equal height with the adjoining wall against the said marshes: to be 6 feet at top, and to batter both ways as $2\frac{1}{2}$ to 1.

A navigable sluice to be fixed across the Tillingham channel, at some convenient place within half a mile of the bridge, at the ferry near Rye, of 13 feet 6 inches in the clear, with a pair of gates pointing to seaward, and another pair to landward, with draw-shuttles or slakers in the latter, and the walls or banks of the Tillingham channel, from the said sluice, downwards, to its junction with the canal before described, to be heightened in such manner and proportion as is described for the main channel from the new canal to Rye.

A dam to be fixed across the present combined channel of Winchelsea and Tillingham, at or near the present new bridge at Rye; the top thereof to be made up to the same height as proposed for the aforesaid new channel from the new canal to Rye, and to have the same slopes as the dam afore mentioned, to be erected upon the Rother.

The channel of Winchelsea, from the present canal to Winchelsea Sluice, to be widened and deepened, so as to be 20 feet in the bottom; to form an inclined plane, so as to fall 2 feet towards the new canal, from the sill of Winchelsea Sluice; the batters of its sides, the heights and slopes of its walls to be the same as proposed for the new channel from the new canal to Rye.

In case the diversion of the land waters shall occasion the out-fall of Wenway Sluice to choke up, then a new channel to be cut, and sluice erected, for the discharge of Wenway Waters, above the proposed dam, into the Rother.

Proper bridges to be made for communication of the present roads.

TO CAPTAIN PIGRAM.

SIR,

YOUR favour of the 9th instant was duly received, and now comes in course to be considered. As almost two years since I was at Rye are now gone over, without any progress being made in those additional works, which were reported absolutely necessary to be done for preserving the harbour, even in the state I found it, it now behoves you to take vigorous measures, and not be impeded by small matters, lest you lose the benefit entirely of what has been done.

That it is necessary forthwith to bring in as much of the back-water as you can procure, appears very evident from what you report, viz. that the new canal is swerved up, towards the head, 8 feet higher than when I saw it, which is very conformable to what you will find in my report, viz.

"This canal alone, exclusive of the outer harbour, will take in above 200 sail of vessels, but yet does not contain a sufficient body of water to produce the necessary scours below; and, furthermore, this part of the canal being liable to silt up, by the deposition of mud brought in by the sea, will, in a few years, be choked up, and rendered entirely useless; the silt being gathered at least 4 feet deep at the head of the canal, since July last, when the harbour was opened. What, therefore, is principally wanting to complete what I apprehend to have been the original scheme, is to bring the land-waters and freshes of three rivers, that now discharge themselves into the old harbour of Rye, through the new harbour, by which means the whole will be kept clear, as appears to me from the following reasons, &c."

As I look upon the Winchelsea waters alone to be insufficient to preserve in the canal a requisite width of channel sufficient for navigation, the grand object is to get possessed of the Tillingham water as soon as possible. The natural course of proceeding is this:

1st. To secure the banks or walls of the Winchelsea channel from the head of the new canal to Winchelsea sluice.

2d. To cut through the dam that at present divides the new canal from the Winchelsea channel.

3d. To raise two dams across the Winchelsea channel, one just below, but as near as possible the head of the new canal; the other, as near as may be to its junction to the Tillingham channel, by which means you are enabled to dig out the channel, as directed, from the new canal to Rye.

4th. This done, you remove the two dams, and, with as much expedition as possible, raise the dam at New Bridge across the united channels.

By this management, you, in the first place, become possessed of the Winchelsea waters, towards making a scour, and also that part of Winchelsea channel that lies between the present head of the new canal and Winchelsea sluice, to add to your reservoir, when you pen in the sea water; and, in the second place, you possess yourself as early as possible of the Tillingham water, and of the great increase of reservoir that will follow upon opening this new channel and that of Tillingham. With these two you will make something of a figure towards the proposed design, and at the same time bring up vessels to Rye by way of the new harbour.

By this method of proceeding, the communication of the Winchelsea and Tillingham waters must necessarily be interrupted during the making this new channel; nor do I know any means of avoiding it, without cutting a fresh channel through fresh grounds, which would not only be a great additional expense upon the undertaking, but only partially remove the objection. If, therefore, the clamours

raised by the seamen and by the country on this occasion are to prevail, I would advise the commissioners at once to give up the undertaking, and spend no more money upon it; for if the means are not to be used by which it is to be effected, it is in vain to make any further attempts; but as I can see no material or lasting inconvenience likely to arise herefrom, I will endeavour to satisfy all reasonable and impartial persons on this head.

And first, with respect to the land-owners upon the Winchelsea channel, those below the sluice will probably expect to be overflown by the tides rising higher upon them from the new harbour than the old; but it appears, from my levelling notes, taken when there, that when the tide flowed 19 feet 9 inches upon the beacon or staff, at the head of the new canal, it rose within 8 inches of the same level in the Winchelsea channel, on the other side the banks, and that when it rose to 20 feet 3 inches upon the said beacon, it rose within 2 inches of the same level in the Winchelsea channel. Hence I conclude, that in the greatest tides there is very little difference, or possibly higher in the Winchelsea channel than in the new harbour, correspondent to what is usually observed, that weak tides are much spent by a long and intricate course, but when all obstructions are surmounted by a strong tide, that the motion, thus acquired, will lift the tides to a greater height in a river, at a distance from the sea, than near its mouth: but, however this may be in the present case, from the matters of fact above stated, it appears that a much greater flow of tide is not to be expected from the new harbour than the old.

In regard to the sewage of the low grounds at low water, it is very evident that this will be improved, because the fall sluice at Winchelsea will then be nearer its out-fall to low water at sea, and, consequently, its course being shortened, it will have more fall in proportion, and thereby penning less dead water upon the apron of the sluice, the water will discharge itself faster through the same openings. It may possibly be objected, that the mud is gathered in the new harbour to a greater height than its present bottom, at the same distance from the sluice, which will be an obstruction; but the land water will soon cut a channel through the loose mud.

I take it for granted, that whenever these waters are first turned this way, a channel will be opened through the mud, which, once done, there is no doubt to be made but that the water will not only maintain itself a channel through the fresh mud, of as great dimensions as it does in the solid ground, but will even deepen the whole, on account of its greater rapidity.

The same reasons will also take place with respect to the lands that lie upon, or sew, by the Tillingham channel, both before and after their re-union with the Winchelsea; because, before they will have the whole channel to themselves, and after they will have both a shorter and a better.

It, therefore, remains that I give my reasons why I don't think the navigation will be spoiled up to Rye Strand.

The harbour or place where ships now lie is entirely within the Tillingham channel, and which they now find sufficient; it, therefore, follows, from the established laws of nature, that, the same causes producing the same effects, the Tillingham waters will maintain the same channel below the new bridge that they do above.

It may be objected, that the united channels below the new bridge, being wider from the union of the two rivers, this channel may grow more shallow, as well as contract the width! I am of opinion that it will not; for since there is constantly

matter floating in the water capable of choking up all the channels, if the land water did not drive it out and keep them open, why does not the Tillingham channel widen and grow more shallow? but suppose the channel was to grow somewhat more shallow, yet, for the time it will be wanted, the same expedients might be made use of as is done in several other channels, viz. a hedgehog to raise the mud occasionally, till the sides have contracted themselves to proportionable width. Some small alteration in point of width may also be expected at the old harbour's mouth; but as the effect can only be in proportion to the cause, if we compare the body of water, either coming down or lodged in that part of the Winchelsea channel, from the new bridge to Winchelsea sluice, with the whole body at a full sea, we shall find the proportion so small as to be almost insensible in its effects; but if, by the objections made by the masters and owners of ships at Rye, they mean that the present channels are not to be diverted or altered till the mouth of the new harbour is effectually scoured, and every thing ready to bring up ships to the town of Rye by the new harbour; as this is in the nature of the thing impossible to be done but by means of the diversion of the said channels, they thereby desire that the effect may precede the cause, which, being contrary to nature, they at once strike at the root of the undertaking, and, therefore, as I have already said, if these argements are to prevail, the best way is to give the thing over at once.

A great deal depends upon the expedition with which these works are performed; for if, while the new channels are digging, the new haven is contracting in width, for want of a sufficiency of back water to keep it open, by such times as they are completed, the new haven will be afresh to dig, and the work become endless.

Difference of circumstances alter cases. Two summers are now elapsed since my scheme was made, and 8 feet more of mud in the new canal; it is, therefore, not only necessary to pursue vigorous measures, but to take such methods in performing the work as may the soonest put it in a state of maintaining itself; I would, therefore, at the first outset, advise, that the new channel from the new canal to Rye be not dug but 35 feet, or at most 40 feet bottom, with slopes as steep as they will stand, as suppose 1 to $1\frac{1}{2}$, according to the quality of the matter, but never steeper than 1 to 1; such a channel will answer all the purposes of navigation effectually; will save a very considerable sum in the first construction; will save a good deal of time, which is now become very valuable, will sooner bring the utility of the undertaking to a proof, and will be as large a channel as the Tillingham can in any degree maintain; which will, therefore, prevent its swerving and contracting in width, while the other channels are completing for bringing in the Rother; and when that is done, in case the rivers themselves do not make it of the width sufficient, it may be completed by tide work, after the more necessary parts of the work are brought to bear. Nor is there any doubt but that in the mean time it will take the Rother and Tillingham land waters, as the former go all through Scotch Flat Sluice, which it has been remarked is no wider, all the passages taken together, than $26\frac{1}{2}$ feet; and as to the Tillingham, its capacity when the tide is checked by the sluice proposed to be built thereon, will be contained in one of the slopes, for even a 35-feet bottom, with the steepest batters, will produce a 65-feet top, and a 40-feet bottom, with batters of 1 to $1\frac{1}{2}$, will produce a river 85 feet at the grass.

It will here be naturally inquired, whether I would build the sluice proposed upon the Tillingham, before it is made to communicate with the new harbour? I

answer, not, for as the tides will go up in the same manner, whether proceeding from the new harbour or the old, the use of that sluice will be entirely to check the tides from coming in too rapidly at the great sluice by having too much room to expand; but as this will not be the case till the communication with the Rother is made, till then it will be useful by enlarging the reservoir.

With respect to the works at the harbour's mouth, you know it was always my opinion, that an attempt to stop the beach absolutely from moving from the west towards the east would be a fruitless and endless task; for let the groins be extended to what length they would, they would fill with beach as fast as they could be raised, and the overplus drive over into the harbour's mouth; I therefore thought it best to let the beach drive away gradually as it came, and in consequence that the extension of the west head could be of no further use than to steer the beach clear of the east head till the wind came so far out to southwards as to tend to heap up the beach upon the shore, rather than drive it along the coast, which end seemed to me very sufficiently answered by the pier as it stood when I saw it, especially with the low groin extended therefrom southwards; for it always seemed to me, that in case the pier was carried out further than absolutely necessary for this purpose, that the quantity of beach that will always be left scattered about the mouth of the harbour, after every south-westerly gale of wind, as it were in its passage, will be too far in the expanded space without the east head, to be carried out by the scours, and then a southerly or south-easterly gale brings it right into the harbour; these have been my notions about this affair, and which have been before expressed.

But as I have not yet found any solid ground-work, upon which I am able to determine how the sea will act in all possible cases; and as you have been pleased to try the experiment of a different procedure, I would advise you not to lower those groins till you are very sure they are upon the whole hurtful; and if so, the thing determines itself; consider also, if hurtful to the harbour, how far they may be beneficial to protect the beach from being carried away to the eastward of the east pier, or how far that may be protected by other means. It is one thing to advise an erection not to be made, and it is another to advise its demolition when made, before it has been sufficiently tried.

You further inform me, that the old timber wharfing, by getting bare, tumbles down faster than they can put it up new. Let me once more recommend to you the use of rubble stones for defending the sides of your harbour instead of timber, not walled, but thrown in so as to form a natural slope. The effect thereof, on many repeated trials, I have never found to fail; and I may say that I saved the two piers of London Bridge whereon the great arch rests, from being undermined, and thereby the arch from falling, the very season I was at Rye. I am of opinion, that had 300*l.* been applied in time in rubble stone behind your east pier, as mentioned in my estimate, that it would have saved greater expenses, and been a lasting repair; but this, as well as several other derangements that happened in the mean time, I suppose must be imputed to the unseasonable stoppage of the bill the first season it was applied for.

I am, with great respect to the Commissioners,

SIR,

Your most humble servant,

Austhorpe, December 29, 1764. J. SMEATON.

RIVER WENT.

Minutes of a View of the River Went, by JOHN SMEATON.

HAVING taken a view of the river Went, Yorkshire, from Went's Mouth to Norton Mills, there appears to me a sufficiency of fall for draining not only the valley of the river Went, but of those lands that have their sewage into the same, and which appear to be of a very considerable extent. It appears to me also, that the principal defects of the present drainage arise from the great crookedness of the river, joined to its being too shallow, and a general want of capacity for taking off the water from so great a tract of country; the out-fall sluice is also of too small a capacity for the drainage of such an extent of country, but seems nearly adequate to the present drain; the mechanism of its present doors, however, is very defective, and they are too low. The river Dunn's water having over-topped the same, the banks near the sluice, which ought to defend the valley of the Went from the floods of the Dunn, being too low and out of repair, have suffered great quantities of water in the late floods to pass into the same. The drainage of the Went's Valley is further annoyed by an influx from the river Dunn in time of great floods, through a low slade of ground between Brafit Common and Flaxley Carr, and from thence proceeds down by way of a drain called the Fleet into Went, a little above Topham Ferry; for as Brafit Common is frequently overflowed by the land floods of the Dunn (and sometimes even by high tides, according to my information), and as Ash Carr, which borders upon Brafit Common, and is the highest part of the slade, lies lower than the surface of the dam in high floods, the water makes its way through the drains and hedges in great quantities into Flaxley Carr, and from thence by the Fleet Drain into the Went as aforesaid. There seems to have been formerly some attempts to have prevented the water of the Dunn from taking this course, by raising a fence bank somewhat more considerable than common, between Ash Carr and the inclosures that lie east and north-east thereof, which so far at present answers the purpose, that by raising dams with sods, &c. in the gateways and low places, a great deal of water was prevented from passing, that otherwise would have passed this way during the great floods last Christmas; and was this bank raised so as to be of sufficient height and strength, would effectually answer the purpose; but the same purpose would be more conveniently answered by constructing a new bank with proper tunnels, for the drain across the head or south end of Ash Carr, from the inclosed ground that lies upon the west side thereof, and abutting upon Brafit Common, extending the same along or parallel to the south hedge of the inclosure, on the east side of Ash Carr, which also abuts upon Brafit Common, to the side of Brafit Fields, being in length, by estimation, about 250 yards; this bank, in one position or other, not only appears necessary for securing the drainage of the Went's Valley, but will greatly improve that of a considerable tract of land lying in the slade aforesaid, particularly about Flaxley Carr, which, except a part of the top waters which are run off down the Fleet into Went, and by another drain leading to the outside of Syke House Bank to the south end thereof into the Dunn, depends altogether upon a small tunnel called Hell Wicket Clough, no more than 8 inches by 12¼, for running off their bottom waters through Syke House Bank into the internal drains, and thence into the Dunn by Black Sea Clough, which clough runs three days on the decline of a flood before Hell Wicket Clough is opened. It further appears to me, that the drainage of Brafit Common, and the lands dependent thereon, will receive no prejudice by the bank before proposed, because Brafit Common lies several feet lower than Ash Carr, both which drain the contrary way, or southward into the Dunn, the present fence bank before mentioned being the line

of partition of the two drainages, at all times, except in extraordinary floods as aforesaid.

Although from this view now taken, I am convinced of the practicability of draining the valley of the Went, yet the depth and capacity of its main drain, together with the requisite height and dimensions of its banks and sluice, cannot be ascertained without an actual level taken thereof; and, in order to ascertain the quantity of land concerned in this drainage, as well as the general directions and length of the drains to be new constructed or amended, and thereby to come at a correct estimate of the same, it will be necessary to take an actual survey of the river Went, from its mouth to Norton Mill, describing the banks, sluice, and main drains that fall into the same, upon a sufficient scale to express the particular loops of the river: and also an outring or flood line of such parts of the several lands that drain into Went, that are liable to be flooded thereby, or for want of a sufficient fall into the same; which outring does not need to be traced with that correctness that the river itself ought to be laid down, but preserving, however, the general bearing between the river and its correspondent part of the outline. The taking of the levels I can myself undertake, if the gentlemen concerned desire it; the surveying part I would recommend to be done by a skilful land surveyor.

Womersley, 31*st March*, 1764. J. SMEATON.

N.B. As the present river is wanting in capacity, and its course so meandering that it is likely to measure by its loops double the right line, I apprehend it will be less expense to make a new cut the greatest part of the length, than to sufficiently enlarge the present river, which cut may be so contrived as to strike a general mean between the properties.

MINUTES

Taken upon the River Went, in Levelling the same, from the River Dunn, at Went's Mouth, to Norton Mills, the 7th, 8th, and 9th of May, 1764, *by* JOHN SMEATON.

Places of Observation.	Rise of the river's surface.	Widths taken at promiscuous places.	Depths taken at promiscuous places.	Height of lands above the water's surface.	Rise of the last winter's flood above the river's present surface.
From the surface of the river Dunn to the threshold of Went's doors, which was 7½ inches under the water's surface there	Ft. In. 1 5½	Bridge 14 9 other places from 10 to 18	Ft. In. — —	Ft. In. Near the Dunn 11 9	Ft. In. Floods of Dunn 13 2
From Went's doors to Hooden Dyke	0 9	from 12 to 18	from 0 8 to 3 0	mean height 6 to 5½	Went's floods about 6 feet.
From Hooden Dyke to Bawn Croft	3 4½	from 12 to 19	from 3 0 to 1 3	from 4 0 to 1 6	from 4 0 to 3 7
From Bawn Croft to Topham Ferry	0 9½	15 0 bridge 14 2	from 1 8 to 2 0	— —	— —
From Topham Ferry to Lake's Mouth	3 6½	from 14 0 to 16 0	from 4 0 to 2 0	from 1 6 to 1 2	from 2 6 to 3 0
From Lake's Mouth to Clough Bridge, at the lower corner of Norton Common	1 9	from 13 0 to 14 0	from 3 0 to 1 2	from 1 3 to 0 6	from 3 0 to 2 6
From Clough Bridge to the departure of the Went from Stubb's Common	2 4½	from 16 0 to 15 0	from 1 10 to 1 0	from 0 6 to 2 6	— 2 6
From Stubb's Common to Norton Bridge	3 7	from 9 0 to 16 0	from 1 0 to 1 8	from 2 0 to 3 0	from 2 6 to 3 0
From Norton Bridge to the floor of Norton Mill Race	1 4½	double course.	— —	from 4 0 to 3 0	from 4 0 to 3 0
From the river Dunn to Norton Mill	19 0				

Hence it appears, that from the floor of Norton Mill Race, to the surface of the river Went at Clough Bridge, there is a fall of 7 feet 4 inches, and from thence to the threshold of Went doors, a fall of 10 feet 10 inches, which added together make a fall of 18 feet 2 inches from the floor of Norton Mill to the threshold of Went doors; and from thence to the surface of the Dunn, there was a fall of 10 inches; but as it was a neap tide, and not then low water, I suppose the Dunn would ebb a foot lower, so that from the tail of Norton Mill to low water in the river Dunn at Went's Mouth at a neap tide, in summer, we may reckon a fall of 20 feet.

The dimensions of the sluice called Went's doors, are as follows:

	Ft.	In.
The width between the walls at top is	12	0
Ditto at bottom	10	0
The width of the opening between the gates at top is	8	7
Ditto at bottom	7	3

WOMERSLEY DRAINAGE.

The Report of JOHN SMEATON, *Engineer, concerning the Drainage of the Low Grounds in the Manor of Womersley, belonging to* STANHOPE HARVEY, *Esq.*

HAVING taken a view of the lordship of Womersley, with respect to the drainage thereof, the 16th and 17th of July, 1764, it appears to me as follows:

1st. That the middle of the manor, through which the drain called Bradley Dyke passes, is in general the lowest part thereof.

2d. My own observation also agrees with information, that the piece of ground called Bradley is the most liable to be flooded of any in the lordship.

3d. That from the run of the water in Bradley Dyke, which in many places is pretty quick, at the same time that this drain is narrow, shallow, crooked, and much obstructed, there seems to be a fall of several feet in the course thereof from Bradley to the brook called Lake.

4th. That there is also a considerable fall from the mouth of Bradley Dyke, to the beginning of Mr. YARBOROUGH's lands, bordering thereupon at the Calf Garths.

5th. That the sewer called Blowell, which in general skirts the lordship on the north, and falls into Lake at the easternmost point thereof, is very well calculated to answer the purpose of a catch-water drain, to carry off the barrier waters, without suffering them to pass into the internal parts of the manor; but passing in general through higher lands seems not well adapted for a main drain, except for some particular parts, which will hereafter be pointed out.

6th. That the rivulet called the Beck, whose continuation after it joins Bradley Dyke is called Lake, and which makes its way through the southern side of the lordship, is in like manner well calculated for a catch-water drain; but as the Beck likewise passes through higher lands, and also carries the springs and flood water from the upland country, it is, therefore, less adapted for the purposes of a main drain for the interior parts of the manor.

Hence, I am of opinion, that the lordship in general will be drained in the best manner by a middle drain, calculated more effectually to answer the purposes of the sewer called Bradley Dyke.

In order to give this drain all the consequence possible, I would propose its out-fall to be as low as may be, that the declivity in the Lake arising from its being loaded with the upland waters, as well as from its crookedness and want of dressing, may be in a great measure avoided. For this purpose, I would recommend that the out-fall of the new drain be carried down to the easternmost part of an inclosure, called Old Ing Spring, that is, to the commencement of Mr. YARBOROUGH's lands, which begin with the Calf Garth next adjoining; from this point I would propose to carry the new drain to Bradley, as much as may be in a right line, without interfering with other property, to pass as much as may be through the lowest grounds, and so as to be as central as possible; with this view I would propose to carry it from the easternmost point of Old Ing Spring, marked in the plan *a*, obliquely for a few rods till it meets the hedge-row between the Old Ing and Old Ing Spring, and to follow that hedge-row to *b*, from thence to pass in a straight line to the south-east corner of the Sodgels at *c*, to follow the south hedge thereof to *d*; from thence in a straight line through Bell Fields, Stocking Pohill Spring, and Stockings, to the south-west corner of Ox Stockings, between Grayson Close and Bradley Dyke at *e*; from thence in a straight line across Broad Oak Spring Closes and Broad Oak Spring, to the point *f*, between Mr. SAVILLE and Lady BELT's lands: from thence in a right line across Hodshon Crofts to the road, and to cross Bradley Dyke, a little above Bradley Bridge, to the Sodgels, at *g*; and from thence in a right line, so as to avoid Bradley Dyke, into Bradley, at the east corner thereof at *h*; from hence branches may be carried at discretion to the more remote parts of the lordship, as for example, one from *h*, across Bradley westward, to *i*, and from thence cross Low Moor to *k*, where it will receive the waters from the springs rising near that point, and also will conveniently receive the drainage from Northings. Another branch may be carried from the said point *h*, across Bradley north, through Pipper Carr, and the rest of Woodhall Farm, to the point *l*, where it is calculated to receive the down-fall waters from the large piece of low ground called Gale.

With respect to Blowell, the Beck, and Lake, I would advise them to be continued in their present course, and their banks to be made up, and strengthened where necessary, towards the interior parts of the lordship, in order to keep out the barrier waters from penetrating thither, and thereby not only contributing to flood the lands, but to load the internal drain.

The bottom of the proposed drain at its out-fall, I would advise to be made as deep as the bottom of the Lake thereabouts when scoured, and to be carried upon a dead level to about the length of Stocking Pohill Spring; from thence to advance upwards upon a regular inclined plane, so as to be full 5 feet deep on entering Bradley at the point *h*, to be 6 feet wide in the bottom, and the sides to slope or batter 1 foot backwards in 1 foot high; so that, supposing the mean depth to be 6 feet, it will be 18 feet wide at top, and there will be 8 cube yards in 1 yard running, and in every acre of 28 yards long, 224 cube yards, which, at $1\frac{1}{2}d.$ per yard, will cost 28*s.* an acre, or 1*s.* per yard running; that is, 88*l.* per mile, and for 2 miles and 1 furlong, which is the length of the proposed drain from the point *a* at Lake, to *h* in Bradley, will cost 187*l.* exclusive of clearing the ground of wood and roots, and exclusive of such bridges as may be necessary where the roads cross the same, which are four in number.

The branch drains need not be above 4 feet bottom, carried upon a regular inclined plane, so as to be at their upper end at least 4 feet below the surface of the lands to be drained thereby.

That part of the lordship about Wye Lands, Kidcoats, &c. which now drain into

Blowell, will drain much better into the new proposed drain, by a cross cut from South-Lane, through Katele's Crofts, to the drain between Bell Fields and Hare Springs; but the lands lying more eastward about Mitchel-Lane, may continue to drain into Blowell, being by this road nearer this out-fall, provided the obstructions between Hodsham Garths, where this drainage comes in, and the out-fall of Blowell into Lake are effectually remedied, and that drain deepened from the bottom of Warfield Wood upwards to the said point, in which space a good deal of fall is at present lost.

These methods, steadily pursued, and strictly adhered to, will in my opinion put the lordship in as good a capacity of drainage as it is capable of, and which will be fully effected when the river Went is made a sufficient sewer for the general drainage of the lands lying thereupon.

N.B. The business herein attended to is the main drain and the diversion of the barrier waters; but it must be understood, that the benefit arising therefrom cannot fully take place till the smaller ditches and sewers that divide and intersect the lands are thoroughly scoured, and such further cross cuts made to lead the water from low places by the most direct road into the main drain, as experience and further observation shall shew to be necessary.

Womersley, 18*th July*, 1764. J. SMEATON.

MISTERTON SAS AND SNOW SEWER.

The Report of John Smeaton, *Engineer, upon the Case of Misterton Sas and Snow Sewer Drain, belonging to the Honourable the Participants of Hatfield Chase, from a View taken thereof,* 14*th August* 1764.

Misterton Sas is the out-fall sluice of the river Idle, built upon Vicar's Dyke, about half a mile from the Trent. This sluice is furnished with two pair of doors, both pointed towards the Trent, so as to compose a lock for navigation of vessels, serving them to pen from the tide water into the drain, and thereby occasion either pair of the doors to be shut. The neat width of this sluice is 17 feet 8 inches, and its height above its threshold a little more than 16 feet. The question concerning it is, as I apprehend, whether an addition of water-way at the Sas, in time of floods, will be of service in reducing the height, and consequently the weight and pressure of the water at those times against the great bank called Vicar's Dyke Bank, which defends the level of Hatfield Chase against the floods of the river Idle.

OBSERVATIONS.

1st. The time that I was at the Sas the tide was out, all the doors open, and the land water had its free course through the same; the depth of water running over the threshold of the doors to landward was 4 feet 7 inches, and the water's surface had a fall from head to tail of the sluice of above 4½ inches, consequently the threshold of the doors to Trentward were below the surface of the tail water 4 feet 2½ inches.

2d. Being met at the Sas by Mr. WILLIAM CROMPTON, he, having made several exact observations upon the state of the waters here during the course of last winter, informed me that, the 21st of May last (which was the day before the moon quartered), he observed that the tide rose at the Trent 5 feet before it sensibly rose at the Sas, the tail water at the Sas being then the same height as this day, viz. 10 feet 10 inches below the S.E. corner of the land wall at the Sas; now, had there been no run of water through the Sas, then the water would have been upon a level from the Trent to the Sas, and, of consequence, it would have appeared that the threshold of the sluice would have been $9\frac{1}{2}$ inches higher than low water mark at the Trent; but as the run of water through the sluice was then considerable, as it was this day, it follows that as soon as the water begun to find any stoppage at the sluice to its discharge into the tail drain by the rising of the tide, that the water at the sluice would begin to swell or rise, though it still preserved its motion downwards, and consequently that it would begin to swell before the water of the Trent was got up to the same level; now if we allow 2 or 3 inches for this declivity from the Sas to the Trent, which must be added to the former $9\frac{1}{2}$, we shall have about 12 inches that the thresholds of the sluice lay higher than low water mark at the Trent.

3d. Mr. CROMPTON also shewed me a mark that the land waters were at on the head of the sluice the day before the bank broke at Idle Stop last winter. This mark I found to be 5 feet 5 inches above the present head water, and, consequently, (allowing $4\frac{1}{2}$ declivity on the tail) 5 feet $9\frac{1}{2}$ inches above the present tail water. He also shewed me a mark, being the height of the water then in the tail of the Sas, when the doors were open and running with a full bore; and this mark I found to be 5 feet $1\frac{1}{2}$ inch above the tail water; consequently, the fall of water at the Sas was then, at its greatest stream, 8 inches.

4th. The width of Vicar's Dyke, at a medium between the Sas and Idle Stop, was about 38 feet at the water line, the depth, at a medium, from 3 to 4 feet, and the water having a smart run all the way, I suppose by estimate that the fall of water from Idle Stop to Misterton Sas was at least 1 foot per mile; that is, between 3 and 4 feet, as I estimate the distance between 3 and 4 miles.

DEDUCTIONS.

As it appears, from the preceding observations, that the pen or head of water at Misterton Sas, occasioned by want of capacity, never exceeded 8 inches in the greatest extremes of floods; hence it would seem that the flood water was never raised more than 8 inches higher than it would otherwise have been, had the Sas been as wide as the river; and this conclusion would be quite just, in case the flood water had been confined on both sides, so as to be obliged to go off as fast as it came down; but as it was at liberty to spread over the lands, where it did not find a passage to its out-fall so fast as it came down, it must keep accumulating till the discharge was equal to the influx.

Now it must be allowed that had the Sas been of a greater capacity, it would have run a greater quantity of water upon a given declivity; consequently, from the first approach, of floods by continually running more water, the accumulation would have been less, and the rise of the water less against the banks, which, in all probability, would have preserved them from breaking at Idle Stop. It is by no means, however, hence to be inferred, that, though the sluice had been as wide as the river, the floods

would have been carried off as fast as they came; for, in the first place, whenever the Trent floods or tides over-rode the land waters, the sluice could not run at all, let its capacity be what it would; and at other times, as the effects depend jointly upon the capacity of the sluice to discharge, and upon the drain to bring the waters to it; and as Vicar's Dyke appears to be defective in point of depth, it must have had a considerable share in the obstruction: for as, from Observation the 4th, there appears a considerable fall from Idle Stop to the Sas, this cannot be otherwise occasioned than by a rise of the river's bottom, which thereby holds up the water, and must obstruct its free passage in all degrees of floods: whether this obstruction has gradually arose by means of weeds, &c. or it has been originally made so, may be a question; but we may reasonably suppose it was originally made so; for, was this part of the river deepened, it would draw off the water from the higher parts of the river in dry seasons to a greater degree, so as to incommode the navigation, and, perhaps, at some times to put an entire stop thereto for want of water over the shoals above.

Upon the whole, then, I look upon the enlargement of the water-way at Misterton Sas, to be an advisable step, and that it may be done in a proper degree relative to the drain, even upon a supposition that it was deep enough, we are to inquire what capacity the sluice ought to have had.

The width of the drain 38 feet at the water line, supposing it to carry 3 feet water, it will batter 3 feet each side, and will have a 32-feet bottom: this ought to have been the width of the water-way, supposing the thresholds laid as low as the water-mark. The greatest extremes of floods rise, per observation, 10 feet above the thresholds of the sluice, and consequently 11 feet above low water mark; so that 11 feet multiplied by 32, the proper width, give 352 feet area, for the water-way; but 10 feet, the present height, multiplied by 17 feet 8 inches, present width give 177 feet area nearly; which, being nearly half of the former, it shews that the present water-way should be doubled, if laid at the same depth.

This enlargement may be made three ways:

1st. By four draw-gates of 4 feet 6 inches wide each. 2d. By two pair of pointed doors, placed near together, one pair pointed to Trent, the other landwards, which latter may be gaged to the height requisite for navigation.

3d. By one pair of doors pointed to Trent, and by a fixed over-fall or weir, gaged to the height necessary for navigation.

The doors in the 2d and 3d method may be the same width as the present Sas, the threshold being laid at the same depth, or about 16 feet wide if laid down to low water mark; but in the 3d method, supposing the height necessary for navigation to be 5 feet above the present sill, then the length of the crown of the over-fall must be 35 feet; for then when the floods rise 5 feet above the top thereof, there will be 175 feet area of water-way, which, with 177 feet at the Sas, will be 352 feet, as required.

The first method has preference in point of expense, but the gates will want opening on the approach, and shutting on the decline of a flood; and, as these are not sudden, or of very short continuance, may easily be done.

The second method will be nearly as cheap as the first, and will need attending at the same time.

The third method will be be somewhat more expensive than either of the former; will be preferable on account of needing no attendance; will do the same office on the extremes of floods; but will be of less service in discharging the water on the decline of floods; which, though of no immediate consequence to the banks when

below a certain height, yet, in case of succeeding rains, the nearer the former are run off, the more room for those that follow.

That the third method will be inferior in point of discharging water on the decline of floods, appears thus: suppose the water reduced so as to make 1 foot over the crown of the weir, its area of discharge will then be 35 feet, whereas it would make 6 feet over the threshold of the gates or doors, and upon 17 feet 8 inches wide, 106 feet area: the weir, indeed, is not confined to 35 feet long, but in this case it would be required nearly three times as long to do the same thing.

The ready discharge of the water on decline of floods will be very beneficial to the drainage of the lands, which drain into Idle or Vicar's Dyke, and therefore ought to contribute if done on that principle.

ON SNOW SEWER.

This drain leads the down-fall water from that part of the level adjacent to Idle Stop, &c. on the south side of the Isle of Axholme, to a place called Ferry, where there is a sluice called Ferry Sluice, by means of which the water of this sewer is discharged into the river Trent, and is the highest sluice upon the river belonging to this level, and, consequently, has the least natural fall; it was, however, necessary, on account of the drainage of that part of the level lying on the south side of the island, the high land of which abuts eastward on the river Trent, and thereby prevents a natural communication of internal drains to carry the waters of these parts to a lower point upon the Trent, without carrying them a great way round about the west end of the island.

This drain is from 15 to 20 feet wide at the water line, and when I was there carried a full body of water, which, at three miles distant from the sluice, had, for the most part, a slow run, except in some places where it appeared to be sanded; there the motion was somewhat more lively; but as the drain was in most places horse-belly deep, quite free from weeds, and no capital obstructions, there appeared upon the whole to be no remarkable loss of fall. As we approached nearer the sluice, the water was in a manner stagnant, the doors being shut by the tide: in this state, the water was just beginning to get upon the surface of the commons from a mile to a mile and a half west of the sluice, which, hence, appears to be the lowest. I observed at the same time that the water was 3 feet 6 inches deep upon the land apron of the sluice.

The sluice consists of two doors of 6 feet water-way each; but the tide being in, and the sluice-keeper absent, there was no coming to the knowledge at this time how the thresholds of the sluice lay with respect to low water mark in the Trent; accordingly, orders were given that this should be taken at a proper opportunity, and the following were in consequence sent me.

	Feet.	In.
Above the threshold	2	2
On the floor	2	9
The fall of water	5	9

Mr. Forster, suspecting the above might not be rightly taken, desired me to go over again, but, being engaged at that time, sent my clerk, who took the levels the

9th of September, being the day before the full moon, and, consequently, between the neap and spring tides: his account was

	Feet.	In.
The surface of the water in the Trent at low water, above the top of the threshold	0	2
Thickness of water going over the threshold	0	6
He was further informed that at dead of neap the surface of the Trent, at low water, was lower by	0	6

From the last observations, it appears that the threshold of Ferry Sluice lies higher than low water mark at dead of neap (which here, it seems, makes the lowest water) by 4 inches; and, allowing 7 inches for the height of the threshold above the floor (according to the former observations), and taking this from 3 feet 6 inches (measured by myself) upon the land apron, there will remain 2 feet 11 inches' descent from the surface of the lowest lands to the threshold of the sluice, and 3 feet 3 inches from ditto to low water mark, neap-tides. Hence, it appears, that as the fall is but barely sufficient to furnish the means of drainage, the whole ought to be constructed upon the nicest principles, and kept in exact order.

It does not appear to me, that any great matters can be done till the sluice is rebuilt, further than an effectual scouring of the drain, and deepening where found necessary; and if banks of $2\frac{1}{2}$ or 3 feet high were raised against the low commons, it would prevent their being overflowed by the water coming down from the westward, when the Trent floods over-ride the drain, and keep the doors constantly shut; but then tunnels with valves next the drain must be laid through such banks, to take off the down-fall from the commons, where the water of the drain becomes lower, otherwise such banks will be a means of retaining the water upon the lands, as well as in preventing their being overflowed. A further temporary expedient might be, to turn as much of the water as may be from the western parts, towards Austhorpe Sluices, which, lying lower upon the Trent, afford a better fall.

When Ferry Sluice is rebuilt I would advise its floor to be laid lower by 1 foot 6 inches, that is, 1 foot 2 inches below low water mark at neap tides, and to be made at least 15 feet clear water-way, to be shut by a pair of pointed doors.

I know this practice will be opposed, upon a supposition, that, being laid so low, it will not run so long, and will be more liable to warp.

But it is very plain, that was the orifice a mile deep, it would always run when the water within was higher than the water without, and that at all other times the doors would be shut; and this will equally be the case if laid high, but with this difference, that, by being dammed up by the floor and threshold, it will not run when the water of the drain is lower than the threshold, though higher than that of the river. To make the advantage clear, let us suppose 1 foot water going over the threshold of the present sluice, which, being 12 feet water-way, the section of the column of water passing will be 12 square feet; now suppose the water at the same height within, and the floor 1 foot 6 inches deeper, then it would run with the same velocity in a column 2 feet 6 inches in thickness and 12 feet wide, which makes 30 feet area of the column; so that in this case the sluice would run as much in one tide as in the other it would run in $2\frac{1}{2}$ tides; but if the width is increased to 15 feet, the area will be $37\frac{1}{2}$ feet, so that it will then run more water in one tide than the present one in three. Again, when the present sluice is run dry, there will be a column of 1 foot 2 inches thick upon the threshold of the new, whose area will be $17\frac{1}{2}$ square feet, which will vent as much water as the present sluice will do when it has 11 inches' water upon its sill; so that the construction proposed will not only,

at all heights of the water, run much more in quantity, and thereby vent the water quicker, but run it down to a lower surface than it possibly can be by the present construction.

With respect to ways, suppose the old and new sluice both warped up to the same height to both without, and the water at the same height to both within, that is, both to act from the same drain: it is plain that the old sluice cannot act till a channel is made through the warp, whose bottom is lower than the surface of the water in the drain; it is also plain that the new one will begin to act at the same time; the only difference will be, that as the warp will lie 18 inches deeper against the doors of one than the others, there may be some little more trouble in clearing the warp from before the doors, so as to suffer them to open at the very first starting; but after each has begun to run, and cleared away a part of their warp, the new sluice will always have the advantage of the old one, because, by carrying a greater body of water, it will open its channel quicker and more effectually keep it open at low water, so long as it continues to run.

The sluice being thus constructed, it will be necessary to deepen the drain, making the bottom 15 feet wide, and to carry it as near as possible upon a dead level with the threshold for 2 miles; from thence it may be regularly inclined towards its head: this being done, in my opinion, it will do its duty without suffering any of the lands to be overflowed by the Trent.

Austhorpe, 19*th September*, 1764. J. SMEATON.

EARL OF KINNOUL'S LANDS.

The Report of John Smeaton, *Engineer, concerning the Works for the Defence of the Lands of the Right Honourable the Earl of* Kinnoul, *lying upon the Rivers Ammon and Tay, North Britain.*

1st. It appears to me that the greatest part of the damage done by floods upon these lands, is owing to the shallow channel of the river Ammon, and the insufficiency of its banks.

2d. That, in order to cure these defects, it will be necessary to carry a bank from a point of land marked out, about half an English mile above Ammon Bridge down to the east abutment wall of that bridge, and from the said east abutment to carry a bank coasting the east side of the river Ammon, at a proper distance to the point of land lying between the mouth of the Ammon and the Tay, which bank ought, at a medium, to be about 4 feet high, and about 20 feet of base, the slopes to be sodded on both sides, or that next the river to be covered with large gravel.

3d. That as the aforesaid work will be of equal and immediate advantage to the grounds now liable to be flooded by the waters overflowing the banks of the Ammon, which are without the border of the estate of the Earl of Kinnoul (and upon which the said banks are proposed to be made), therefore the proprietors to be at a joint expense with the Earl of Kinnoul for the completing thereof.

4th. But in case the said proprietors do not choose to be at their proportion of expense, then I would advise the Earl of Kinnoul to make good the breach that has been made in the land contiguous to the bulwark erected at the end of the new road leading from Perth to Ammon Bridge, and to make the whole effectual, to take

down the remains of the present bulwark, and to make the whole of rough or rubble stone from the quarry, added to the present materials thrown together bank fashion, so as to slope 1½ feet base to 1 foot perpendicular towards Ammon Bridge, and 2½ feet base to 1 foot perpendicular on the side next Perth, to make the same 2 feet lower than the surface of the ground on which the said bulwark abuts in the middle between the abutments, but to raise the same somewhat higher than the said surface at the ends where the bulwark abuts upon the same, and to extend the rubble work 1 rod at each end on the plain surface; and also to line the banks or abutments with rubble for 1 rod above, and 2 rods below the bulwark at each end; which said bulwark is intended to confine the waters of the Ammon or Tay in moderate speats from flowing down the old road, but in high floods to break the rapidity of the current, and to admit the same to have an easy passage over the bulwark.

5th. In regard to the great bulwark, which was erected at the joint expense of the Earl of KINNOUL and the town of Perth, in order to preserve and regain the lands from the incroachments of the river, before which it has been raised, I am of opinion that the lands might have been secured in a much easier and cheaper method, as hereafter described; and, with respect to the regaining of lands, they could never be worth the purchase: it further appears to be built of very bad stone, and, therefore, will be subject to a considerable annual repair, greater than will support the banks intended to be supported thereby; yet as some good has been produced from it, though not adequate to the expense of building or maintaining it, yet I would not advise any erasement thereof, but to leave the same to such events as the floods and weather may produce, and which in a state of rubbish, by keeping the channel of the river at a distance, will tend to lessen the repairs, which otherwise might be necessary on the said banks; and whenever the river shall begin hereafter to make any depredations on the land, to apply the cure immediately to the part affected, which I would advise to be done in the following manner:

Let a quantity of rubble stone be brought from the quarry, the more angular, rough, and irregular the better, and, at a medium, as big as a large cabbage; let as much be thrown up against the broken place (almost as steep as it will lie) as will form a natural slope against the bank as high as ordinary floods reach, or as the surface of the lands where lower, sloping away the land above the rubble where higher, observing to avoid all jetties and protuberances as much as may be, so as to give the water as free a passage as possible. In general, I would advise my Lord KINNOUL, in case of breaches or incroachments upon the land by this or any other river, not to have recourse to jetties, or walls of masonry, but to line the banks with rubble thrown in, so as to form a natural slope, and the length of the work the nearer it is to a parrallel direction with the current the better; by this means the quantity of materials necessary to form a jetty, breakwater, or bulwark (which being designed to resist and oppose the current must be made stronger) being disposed along the face of the bank, will in general be sufficient to defend the whole length that could be expected to be effected by the jetty; and with this difference, that the edge formed by the jetty itself generally forms a pit or incroachment upon the land just below; whereas the work disposed in a parallel direction to the current equally protects and equally resists; so that the wreck and sullage of the river, in time, filling up the interstices of the rubble, makes it grow firmer, whereas the constant action of the current upon the weakest part of a bulwark or jetty, viz. the termination thereof, puts it in a constant state of waste and decay.

By the application of rubble, we have stopped the most formidable breaches where the river has had its course through; by means thereof we secure our banks

and the aprons of our locks and dams upon the river Calder, over which last the water, in time of floods, has much greater rapidity than the natural current of the Tay possibly can have in the neighbourhood of Perth; in short, we make use of it in all our defences upon the Calder, and have never found it to fail. I know it will readily be urged, that the Tay being a larger river than the Calder, that what will do upon the one may not do upon the other; it is true, that the Tay is a wider river, but it does not appear to be more rapid, that depending chiefly upon the fall, which, in the Calder, is above 8 feet per mile, for above 20 miles together, that we are concerned with it, nor does it appear that the Tay in time of floods rises to a greater height above its common surface. Hence I infer that the action of the Calder upon its banks is as great as that of the Tay upon its banks, because the quantity of this action depends upon the height and rapidity of the water acting immediately against them, and not upon that which passes by at a distance from them, so that the width of the river is totally out of the question.

In general, I would advise my Lord KINNOUL to be as sparing of these kinds of works as may be; for without a great deal of land be got or saved by a moderate quantity of work, though the method I have chalked out is the plainest, easiest, most durable, and cheapest of any thing I know, where stone can be procured at a moderate expense, yet that land would come very dear that would require covering with rubble.

Perhaps it may be suggested, that danger may arise from letting the great bulwark go to ruin; for when in that state, if an inconvenience should happen to arise, it would be much more expense to repair than to keep it in repair. But this I apprehend to be quite otherwise; for a mass of rubble thrown promiscuously together, upon the ruins of the present bulwark, will be more lasting than the present one can be with its present materials and form, and can always be repaired by addition.

Upon the whole, it appears to me, that the greatest damage done, or likely to be done, to my Lord KINNOUL's estate at this place, arises from currents of water topping the banks of the Ammon, and running over the surface with great rapidity, thereby taking away the earth, wearing gullies, and leaving tracts of barren gravel in its room, which will be the most easily prevented by embanking the Ammon as before described, and stopping the mouth of any such gullies as appear to lead the waters upon the land; yet, notwithstanding, this will not prevent the back water from returning up the slades from below, and standing upon the land to the same level as the Tay at the places of communication; however, the water there being in a manner stagnant, the ravage above mentioned will be prevented; but a total prevention of the floods from coming upon the lands can no otherwise be effected, but by embanking the whole round, both against the Ammon and the Tay, so as to be flood-proof against the greatest extremes, with a proper sluice to let out the down-fall and soakage waters when the floods are over; and this, though I look upon it as a practicable work, yet the difference of rents upon the quantity of grounds concerned, does not seem to encourage an undertaking so considerable.

Having mentioned the expediency of banking against the Ammon, it may be understood I looked upon the Ammon waters to be the sole cause of the overflowings already mentioned; but the case appears to me thus: when the Tay is flooded, it would revert upon the channel of the Ammon to the same level, though no current was to come down the Ammon at all; and were the banks of the Ammon lower than those of the Tay (as they really are about Ammon Bridge), the Tay would run up the Ammon, and first, and most strongly run over at the lowest places, viz. near Ammon-Bridge; but if, at the same time that there is a flood in the Tay,

there is one in the Ammon also, as must often happen to be the case, the current of the Ammon being stopped by the Tay, the Ammon must then be forced to rise to a greater height, till it can over-ride the Tay's water, and, for that cause rising to a greater height, will the more plentifully overflow its banks; but, were the Tay low while the Ammon was in a flood, I do not apprehend much mischief would ensue from the Ammon alone.

With respect to Bussey Mill, I find that with the quantity of water issuing from the boot at the time I saw it, there is a power, when well applied, and the machine rightly managed and used, of grinding a Winchester quarter of wheat per hour, and that such an erection, if done here, would cost from £400 to £500.

Austhorpe, December 13, 1763. J. SMEATON.

RIVER DEVON NAVIGATION.

Some Points relative to an intended Navigation upon the river Devon, stated by Lord Cathcart, and answered by John Smeaton.

Sir,

If I rightly understand you in our late conversation, your opinion upon the points stated to you was as follows.

1st. That if the isthmus of Long Cars, betwixt Alloa and Cambus, were cut with a canal, the sides properly sloped and faced with rough stone (as you may more particularly explain in the margin), and the present channel of the Forth allowed to remain as it does, such canal, the banks being of a height to contain the tide, would not endanger the adjacent lands by bringing more water that way than is intended, will have no occasion for flood-gates, and will be an effectual improvement to the navigation, by avoiding the Thrask shallows, and other impediments.

My Lord,

The points stated by your lordship contain the substance of what passed betwixt your lordship and me in conversation; therefore, to avoid repetition, shall note in the margin what I have occasion to enlarge upon, or wherein your Lordship seems to have misunderstood me.

1st. In this particular I understood your Lordship that the Thrask shallow is a flat shallow at low water, not of such a height as to pen the water above it, but merely an impediment to navigation, through want of depth. This being the case, a canal cut through the isthmus will have no other effect than here described, and the sides of the canal being sloped from the proportion of 2 to 1, to 1 to 1, as the soil may happen to be from a loose earth or gravel to a firm clay, and being covered with rubble quarry stones (suppose one foot thick), so as to make a complete cover, this will not only defend the bank from the action of the current, but of the waves occasioned by the wind; but in case the shoal above mentioned makes a considerable pen, so as to determine the current much more strongly through this new canal than through the course of the river, it will be necessary to

defend the bottom also with stones, to prevent the action of the water from deepening the same, and thereby sapping the foundation of the stone facing, and in consequence bringing down the banks and widening the canal. In case the pen should be very considerable, it would be necessary to build a lock upon it; but the determination of this matter depends upon the length of the canal, and difference of level of the surface of the river at the head and tail thereof, taken at low water, when there is no fresh in the river, as also upon the quality of the ground forming the bottom.

2d. That if the river Devon was navigated by Sir JOHN ERSKINE, from the Cobble Crook to Cambus, by means of sluices on Tilli Body Bridge; that navigation may be better effected by the canal and lock proposed than it could have been by the sluices, and the ground through which the canal passes, viz. from Minostrie Lint Miln Dam to Tilli Body Bridge, being clay and perfectly level.

2d. There is no doubt but that locks are preferable to simple sluices.

3d. That from Cobble Crook to Sauchie, there being only two small fords in the way, the navigation may be effected by one lock and dam at the lowest ford, in case it should not be found better to avoid the fords by cutting from deep water to deep water, and making a channel behind the fords; but that this expedient, which is the best, cannot take place if the present fords act as dams, and the new cuts should have the effect of letting down the river, and creating other fords in parts where the upper part of the navigation is intended to go.

3d. I beg leave to add, that if a dam is built upon the ford, or the upper ford be supposed to act as a dam, a canal with a lock upon it, brought down so as to drop into the river below the lower ford, it will also equally answer the end if found most easily practicable. Also, if, instead of joining the deeps by cutting a channel behind the fords, the fords themselves be removed, or channels through them be made, this will also answer; but in this case, care must be taken to make the channels on such side where the principal tendency of the water is to act in floods, otherwise they will be liable to be thereby filled up again.

4th. That you recommended carrying the navigation by locks out of the river at Old Sauchie, and raising it into a canal, upon the level of the river above Tillicoutery Dam, to be carried in the line and direction of Lord CATHCART's aqueduct (till it falls under ground into the pipes where it crosses the Devon), and there to be carried in an aqueduct bridge

4th. This seems to be the method from what was described to me upon the plan: but as it is scarcely possible to form adequate notions without ocular inspection, much must be left to the judgment of him who executes, in respect to the choice of the ground.

over the river, and continued to the dam, and from thence to the foot of the Rack Miln Dam, where there must be locks to surmount the said dam, in case the navigation is carried on to Vicar's Bridge.

5th. That the level of the stretch from Sauchie to Melloch Foot is proved by Lord CATHCART's aqueduct and the present state of the Devon, which is already navigable betwixt Tillicoutery Dam and Melloch.

6th. That the rising of the river in times of flood, so as to overflow the aqueduct bridge, does not infer any danger, either to the bridge or adjacent lands.

7th. That, upon the whole, as thus represented to you, the navigation of the Devon, and the improvements of the navigation of that part of the Forth, between Cambus and Alloa, seems very practicable and, from the nature of the levels, at a moderate expense, considering the length of the navigation.

8th. That from your experience in navigation bills, and their consequences when passed into acts, it is your fixed opinion, that the execution can neither be answered for, nor depended upon, in the hands of trustees, and that the only safe and sure way is for the proprietors of coal within reach of Devon, and Mr. ABERCROMBIE, to be the undertakers, or for Lord CATHCART to be the undertaker, with a proviso in favour of the other coal proprietors and of Mr. ABERCROMBIE, in case they shall choose to recede, and naming a number of Commissioners to be

5th. Certainly, supposing the said aqueduct to be carried upon a level.

6th. It must be supposed that the dimensions of the water-ways, breadth and depth taken together, under the aqueduct bridge, must be such as to vent the water as fast as it comes in at extremes of floods, and also the ice in winter; otherwise great damage may ensue both to the works and adjacent lands, unless a certain length of the side walls of the bridge that sustain the canal are very strongly capped with stone, and left lower than the rest, for the water to flow over like a dam; but this expedient I would not recommend to be used, if it can be possibly avoided. N.B. I don't at present remember why the passage of the river cannot be obtained by raising a dam in the river below the intended place of crossing.

7th. Agreed.

8th. This I have enlarged upon in my letter from Newcastle; I have only to add, that in this case the adventurers should be fixed down to take a reasonable toll for coals from the other coal owners, who may not in their present situation choose to be adventurers themselves, otherwise the proprietors of the navigation may choose to lose those tolls altogether, to prevent the others from working their collieries, which would be a detriment to the public.

referred to, and to judge betwixt the undertakers and other proprietors in all questions that may arise now or hereafter, with respect to damages, &c. in consequence of this act, by which means the parties interested in the toll will attend to the execution; and as the toll never can be suffered by the undertakers to rise to the price of land carriage, the difference, whatever it is, is so much saved, and therefore a benefit to the public.

9th. I forgot to ask the dimensions and size of the boats proper for the carriage of coal, and how deep water they will require.

As also whether is a better method to land the coal from the canal on the pier, and load them from thence on board the ships, or to let the boats down into the river by locks, and put them on board directly from the lighters.

Your certifying the above to be your opinion, or marking on the margin where I have misunderstood you, with some explanation, for the satisfaction of the other persons concerned in this bill, relative to the 1st, 6th, 7th, and 8th, articles, with your opinion upon the 9th, will very much oblige, sir,

Your most obedient
humble Servant,
CATHCART.

London, Feb. 11, 1765.

9th. The size of the boats used for carrying coals is various in different places, and differ in size, shape, and draught of water, according to the convenience of the place; but I apprehend that such boats as are principally used in the Yorkshire rivers, will answer as well as any for such a navigation as proposed by your lordship, viz. 54 feet long, stem and stern-post included, 13½ feet wide, and 3 feet draught of water; those will carry from 20 to 30 tons, according as they are more light or heavy built.

If the ships were always ready to be loaded, when the boats brought down coals, it would certainly be the most advantageous to lay the boats alongside the ships: but when the ships are not ready, they must necessarily be landed upon some quay or wharf common to both, which I apprehend should be covered like the coal staiths at Newcastle. Whether the quantity that can be delivered alongside the ships, in proportion to what cannot, together with the advantage of an open communication of the canal with the Forth, for the conveyance of other goods and merchandise, will make it worth while to make the necessary lock, is a matter of convenience that can only be determined upon the place, by those well acquainted with the nature of the trade thereof.

The cases stated, considered with my answers thereupon, contain the opinion upon these matters of,

My Lord,
Your Lordship's most humble Servant,
Austhorpe, 20th April, 1765. J. SMEATON.

QUERIES, &c.

Communicated by LORD CATHCART, *relative to a Navigation on the Forth, November* 5, 1767.

BY the Report of Messrs. WATT and MORISON to the Board of Police, it appears,

That a navigation may be opened at a small expense from the valuable woods, lime and slate quarries of Aberfoil to the bridges of Aberfoil upon the Forth.

That it may be continued from thence to Cardross, by a lock below the ford of Cardross.

That it may be continued from thence to Frew by a lock below the ford of Frew.

That from thence the river is navigable to a rocky ford called Craig Anet, betwixt the Bade and Drip Coble, which is two feet higher than Craigforth mill-dam, which last is three feet higher than the cruives of Craigforth, which are four feet above the neap-tides, in the lower part of the Forth.

That a dam of three feet should be added for the sake of deepening the water, as far up as the Frew, which water so raised would be 12 feet above the neap-tide.

That a canal near a mile in length, from a point above the Bade, across level ground of a clay soil, with a lock of 12-feet fall, would complete the navigation from Aberfoil to the tides-way at the new mill of Craigforth.

And that the navigation from thence downwards may be shortened about seven miles by four cuts, as expressed in the plan, below Stirling Bridge.

It appears by Mr. SMEATON's Report to the proprietors of the Devon collieries,

That Cambus, with proper improvements, may be made a very convenient port for exporting sea-coal, and for accommodating ships in that trade.

That the river Devon may be rendered navigable from Mellock Foot to Menstrie Lint mill-dam, which space includes five collieries.

And that the navigation may be continued from Menstrie Lint mill-dam to the tide-way in the Forth at Cambus.

Menstrie mill-dam is 12 feet above the neap-tides, therefore on a level with the water above the three-feet dam at Craig Anet, in the Forth, projected by Mr. WATT.

Suppose $2\frac{1}{2}$ feet added to the height of each dam, the water in the Forth above Craig Anet, and in the dam above the Lint mill-dam, will still be equal, and $14\frac{1}{2}$ feet higher than the neap-tides.

The ground is clay, and very level from Menstrie Lint mill-dam to a point betwixt the bridge at Stirling and the new mill at Craigforth, where the banks on both sides are pretty high; and Mr. WATT's canal may be brought, upon very favourable ground, to a point opposite to it.

Suppose an aqueduct bridge of a proper dimension, erected across the Forth, betwixt these two points (the distance being 300 feet), there will be dead water from Frew to the Lint mill-dam, by which the upper part of the Forth will have an easy, short, and open access to the Devon collieries, and also have an opportunity of dropping into the tides-way at Cambus, by locks of $14\frac{1}{2}$-feet fall, the advantage of which, considering how much lime-stone, slates, wood, &c. must come down, and how much coal must go up the Forth, including the consumption of the town of Stirling, and the inhabitants of those parts of the country that come through Dumblain; and that the lock at Craigforth new mill, and a great length of navigation, and the loss of time in waiting for the tide, will be saved,—is extremely obvious.

The only circumstance of doubt is the practicability and expense of the aqueduct bridge, the length being 300 feet, and the bottom of the river clay, and far

above rock; if it is executed in stone, the number of piers which it will require, as the level will admit of so small a rise for the arches, and the foundation which must be piled, it is apprehended must render the expense enormous. If it is executed in wood, upon the plan of Julius Cæsar's bridge, which is well adapted to resist ice, or other floating bodies, or upon any better more modern construction, it is apprehended it would come much cheaper, would stand against the force of the stream, and of the ice in winter, and would not be affected by the land floods, which cannot rise to the sole of the aqueduct, but must be liable to the expense of repairs to which a stone bridge would not be subject.

Mr. SMEATON, who is acquainted with the nature of the rivers and country adjacent in question, and skilled in every expedient that may facilitate the junction of the two level canals, by an aqueduct, is desired to say,

1st. Which of the two plans, the aqueduct bridge and canal to join it to the Devon at the Lint mill-dam, or the lock at Craigforth new mill, seems, upon the face of them, the most eligible for the inhabitants of the upper part of the Forth?

2d. If the aqueduct plan seems the most eligible, what *data* it will be necessary to furnish Mr SMEATON with, to enable him, at his leisure, to make out a design for the bridge?

3d. Does Mr. SMEATON think that the boats recommended for the Devon, drawing three feet water, of 13½ feet width, and 56 feet long, will answer all the purposes of the Forth boats, or would it not be proper to allow for a foot more draught of water, in order that their slates, &c. may be carried coastways, and that the locks and canals be for that purpose proportionably deepened?

4th. Suppose the aqueduct bridge rejected, and the lock at Craigforth Mill adopted, will it not be expedient to make the four cuts in the Forth, as marked in the plan; and if any, but not all, which of them?

5th. The ditches from Tillibodie Bridge to Manner Pow are from 8 to 10 feet deep, and about 12 feet wide, and are on a level with the Devon, at Tillibodie Bridge, and with Sir JOHN ERSKINE'S canal at Cambus, would it not be right to build a lock at Manner Pow, and to enlarge these ditches, that Upper Forth boats might get by that tract to the collieries, whereby upwards of 6 miles' navigation would be saved?

ANSWER

To five Queries concerning the Improvement of the Navigation of the River Forth from the River Devon upwards, communicated by the Right Honourable the Earl of CATHCART, *in a Letter of November 11th, 1767, to* JOHN SMEATON.

1st. If the communication of the Devon collieries with the upper Forth was the sole object in view, then the long canal, from above Stirling to the Lint Mill Dam, upon the Devon, seems very well adapted for that purpose, and in that case would merit serious consideration, how far the aqueduct bridge over the Forth (which, indeed, seems the only difficulty) might not be (under the specified circumstance of elevation) an executable scheme; but if the expense and difficulties of executing such a bridge there, as well as the expenses of land, cutting bridges, and other contingencies attending the proposed canal be considered, and that at last it will not save above 5 miles* of distance, though none of the loops below Stirling are supposed to

* The distance up the Devon being taken into the account.

be cut; if, on the other hand, the advantages arising from a free and open navigation to all parts of the Forth below, for all kinds of traffic, be put in the other scale, I cannot hesitate to say, the advantages being considered with the expense, and probability of trade, that it appears to me, on my present view of the proposition, more eligible to lock down into the Forth, near Craigforth new mill, and below that to keep the river.

2d. This is answered by the first.

3d. If the vessels were made of greater draught of water than 3 feet, and wider than 13 feet 6 inches, they would undoubtedly be more safe in navigating the broad part of the Forth, and coasting, and could venture, and keep out in worse weather; but such vessels, as described for the Devon, not only go in the narrow rivers in Yorkshire, &c. and down to Hull, but even go out to sea, and cross the Lincolnshire washes to Spalding for corn, to be carried in the same vessel to Leeds, Wakefield, and Halifax; but as it is obvious that if the bulk of the vessel is increased, it will occasion greater expenses in executing the locks, cuts, canals, &c. it may, therefore, be worth while to consider, with *the degree of trade that is probable*, whether it may not be eligible to save a capital that must thereby be expended by changing: for though the vessels above mentioned can, and do go as before set forth, yet the bulk of trade is carried on by changing vessels at Armine, that is, as soon as the river is capable of receiving sloops of 50 and 60 tons.

4th. The most important object in making artificial navigations, is to avoid dead stoppages by want of water, &c. In many principal navigations in England, vessels are frequently stopped in dry seasons for one, two, and three days at a time, sometimes for a week together. Now, if they had a certainty of going at a particular time of tide, twice in 24 hours, they could suit their times accordingly, and would be content to go several miles about, if they had a certain passage, rather than lie still so long together; for this reason, cuts are seldom made merely and simply for shortening distances; and though in the district under consideration the river is remarkably crooked, yet, as the rest of it, both above and below, is but little better, it may deserve a serious consideration whether it is worth while to make any of the cuts proposed below Stirling; for as, according to the plan I have, the difference of distance is but about 5 miles, with the cuts and without them, the engineers would, therefore, do well to consider, from actual admeasurements of the respective lengths, and levels taken, how deep, how wide at bottom and top, each cut will be required, in order that they may be materially more passable than the present fords; and to effect that, how deep they will be required to be dug below low water, what land must be cut and covered; these things being ascertained, and proper estimates made from the price and quantity of excavation, the price and quantity of land, the charge of pumping water while the digging is going on under level, and the damages that may be done by the river's breaking in while the works are going on in that situation, also the charge of making dams to turn the water from the cuts, or, if none, the time lost in getting the tracking horses across the old loops; I say, all these things considered, and estimates formed from particulars, will soon direct you, whether, from the probable quantity of trade, the expense of any, all, or some of these cuts, will be balanced by the time in the passage respectively saved. The two upper ones seem the most advantageous, the rest in order as they are lower; but it will be right to have a power in the Act to make any of these cuts; that after the necessary canals, locks, &c. are made, if it shall appear from the quantity of trade, and the goodness of the funds, that the thing is eligible, there ought to be a power of doing it without a fresh application.

5th. The expediency of this step consists in the facility in doing it, because the advantage will wholly consist in the trade with the Devon; for it will not be worth while for a vessel at the mouth of the Devon, and going up the Forth, to make use of this passage, because, in going round the great loop, she will be thrown about only 1½ mile more than the artificial passage, in which latter she would have to pass two locks.

It is to be observed, that by a double entry into Devon the leakage will be double; and if made use of as a passage up and down the Forth, each vessel will expend two locksful, except in cases of meetings.

Austhorpe, November 21, 1767. J. SMEATON.

LORD CATHCART'S QUERIES RELATIVE TO THE RIVER DEVON.

Mr. Smeaton to consider the Cambus, and the river below the Cambus, and to give his opinion, whether the Cambus can be made a proper port of exportation for great coals, and if it can, by what means, and at what expense.

Objections. Want of depth of water, expense of making a new port, loss of time to ship-masters to come so much further; danger from ice in winter.

If either impracticable, or too expensive, Mr. Smeaton will consider whether the coals cannot be carried in boats down the Devon and Forth to Alloa, and there shipped for exportation.

Objections. Coals carried down to Alloa by water cannot be folded there without great expense, but must be loaded from the lighters, which ship-masters object to, for reasons perhaps frivolous, but will best be collected from themselves, and judged of by Mr. Smeaton.

If coals brought down the Devon can be exported either from the port of Alloa, or of Cambus, Mr. Smeaton will then consider the best method of rendering the Devon navigable, from Mellock Foot to the Forth, either by a canal, or in the bed of the river, or partly by one, partly by the other, calculating the expense of the whole, and specifying the dimensions of boats, what they are to carry, and how to be drawn.

The size and dimension of boats will depend upon the use intended; if they are not to be let into the Forth, they may be very long, very narrow, and very shallow, which will reduce the expense of the canal. If intended to go down to Alloa, or up the Forth, they will not admit of the same construction.

N. B. The possibility of going up the Forth by water from the collieries would be a great conveniency, because were the navigation opened above Stirling Bridge by locks at Craigforth, Frew, and Cardross, all the country on each side the Forth might, as well as the town of Stirling, be supplied by water-borne coals from the Devon collieries.

If Mr. Smeaton finds any species of navigation practicable and advisable, he will favour the coal masters with his ideas of the proper Act of Parliament to be petitioned for; and of the places, proportion, and manner of collecting tolls, and manner of shipping the coals either from boats or quays; and if he will undertake, or recommend an undertaker for the whole, or the locks only, and on what terms.

To this may be added a remark of Messrs. Mackell and Watt, lately made; that is, that a canal may be carried upon a dead level the whole way from Tillicoutery to a point opposite to the schoolmaster's house at Alloa, following the foot of the rising grounds the whole way, that it will be about 30 feet higher than the sea, and may

either be carried betwixt banks across the flat grounds, which is not far, to the shore, otherwise the flat ground may be cut to bring the Forth up to the low grounds.

This would save locks and waste of water as far as Tillicoutery, and might be joined by a canal from Mellock Foot, the level of which would be a very little higher, and might require a lock.

Levels.	Ft.	In.
From Forth to Sauchie	18	10
From Sauchie to Mellock	19	6
From Mellock to Vicar's Bridge	39	6
	77	10

THE REPORT

Of JOHN SMEATON, *Engineer, concerning the Practicability and Expense of making navigable the River Devon, in the County of Clackmannan, from Mellock Foot to the River Forth.*

THE river Devon falls into the river Forth about 2½ miles above, or to the west of Alloa, but according to the turns of the navigation, up Forth, about 3½ miles. There are several valuable collieries upon the slope of the hills that decline towards the river Devon, the coals of which are now carried to Alloa over land, in order to be put there on board vessels capable of carrying them to all parts where wanted. The more easy carriage, therefore, of those coals, from the collieries to the shipping, is, as I apprehend, the principal object of the present proposed navigation.

At the mouth of the Devon the extreme spring-tides are said to rise 20 feet perpendicular, and at such tides the water flows one foot higher than the top of Cambus Quay, which is an old quay, at which formerly coals were shipped, about a furlong within the mouth of the Devon. The common neap-tides are said to rise within five feet of the top of the said quay, and that then there is 12 feet water in the river Devon opposite the said quay. When I was there, the morning of the 20th of November, 1766, being the fourth day after the full moon, it appeared, that the mark left by the last tide was as high as any that had been that spring, and what might be called an ordinary spring-tide: this I found had been within 1 foot of the top of the said quay; and, consequently, being 4 feet higher than the ordinary neap-tide mark, made 16 feet water in the river opposite the quay. At the time I was there it was almost low water in the Forth, and then the current of the Devon ran with a considerable declivity towards the Forth, having a fall of not less than 2 feet.

The declivity of the bottom of the river, from Cambus Quay to the Forth, appears pretty regular; the bottom opposite to, and above, the quay seems to be mud intermixed with large tumbling stones; these stones being removed, the mud would wash away, so that I look upon it as very practicable to make 2 feet more water at Cambus Quay than at present, that is, to make 14 feet at ordinary neaps, and 18 feet at common spring-tides.

If more water than the above should be requisite, I should look upon it as more eligible to dig out a new channel and harbour from the Forth, which may be done on the west side of the Devon, the ground there being low and flat, and gently rising from low water mark; this work may, therefore, be done at a moderate expense in proportion to such a work, but yet must, in digging, walling, &c., amount to a considerable sum, more than would be necessary to rebuild and enlarge the old quay and deepen the river, as aforesaid.

To the safety of the place there seems to me no material objection; for as to ice in winter, it cannot do much harm, as it must be much broken in passing the bridges and dams before it gets to the Cambus. It is no peculiarity of the river Devon, and is the case, more or less, with every seaport which has the advantage of being scoured by a fresh water river, which is, in itself, very desirable.

In going up the Forth from Alloa to the Cambus, the navigable channel of the river makes one large half moon; but as it is, in general, sufficiently spacious for vessels to turn, this case also differs little from what is common in other tide rivers: it will, undoubtedly, be some hinderance to vessels going $3\frac{1}{2}$ miles further up, but as this can hardly ever be attended with more than one tide loss of time, and often without the loss of a tide, it may as well be said, that the coals ought to be carried down to Kincardine Road, to prevent the possibility of the loss of a tide in going to Alloa. The principal impediment in getting betwixt Alloa and Cambus, for vessels of burden, is occasioned by a shoal called the Frask; and this arises not so much from want of depth of water, as from the narrowness of the channel; for in sounding the river at low water the day above specified, we sounded in the channel over the Frask no less than 5 feet, which, though the shallowest place between Alloa and the Cambus, seems yet a very sufficient passage, at all proper times of tide, for vessels bound to an harbour, where they could lie dry at low water the same tide.

This shoal seems to consist of a ledge of stones which lies almost across the river from S. W. to N. E., confining the channel close in with the point, which is an unnatural situation for the channel, but arises from the greater softness of the ground in that part where the channel is. As this shoal is short, according to the direction of the channel, it seems very practicable to remove the stones, so as to increase the same in width. There is at present a sufficiency of width, when proper beacons are set, for the passage of vessels right up and down, but not of those turning to windward.

This shoal may also be avoided by cutting through the neck of land; but if the great depth that such cut will be required (the ground seeming there 18 or 20 feet higher than low water), the depth to which it must be carried below low water, and the great width that it must have in the bottom, to make it a more eligible passage than by the Frask, be considered, I believe it will appear, that the canal may be extended to Alloa for almost as little, if not less, expense. It, perhaps, may be expected, that if the cut is made narrow, and down to low water, that in time it will wear itself wider and deeper, and so indeed it may; but whether this will happen in the compass of seven years or twenty, or whether it will ever happen, so as to be (as already said) a more eligible passage than the Frask, I think is out of the power of any man to say with certainty; for it is to be observed, that till it becomes much wider than the Frask, and equally deep, it will be more difficult to turn to windward through it, on account of its greater length.

As the natural declivity of the river from head to tail of this supposed cut is very little, unless a dam was put across the main river to force the current through the cut with some considerable velocity, the water could not, in its natural state, be expected to operate very speedily; and as the width of the river through its several channels in this place is very considerable, such dam would be very expensive, would obstruct the navigation while the new channel was wearing larger, and by depositing of the matter and diverting the present channel, there is no saying, but that after all a shoal might be formed in some place where now there is none, as troublesome as that we would mean to avoid; for these reasons I cannot, in my present view of the matter, recommend this division of the river from its present channel.

With respect to the dimensions of the canals, cut out from the course of the river Devon, they depend upon the kind and sort of vessels to be employed, and the sort of vessels will again be determined by the uses to which they are to be applied.

If the vessels are to be employed merely in bringing down coals from the collieries to the quay, where the ships load without going into the Forth, vessels long, narrow, and shallow, may be used with advantage; but if intended to go up and down the Forth, they will require a different construction.

It seems to me, that if the navigation be limited to the canal only, without going into the Forth, it will be attended with many inconveniences, but that it will be of more general use, if capable of containing vessels capable of going up and down the Forth, as well as of navigating the canal; for, by this means, vessels may be loaded at the Cambus Quay, or at Alloa, as may be most suitable to the sea vessels to be loaded; or they may be carried up the Forth to Stirling, and up to Gartmore, in case the navigation above Stirling is completed, which, if confined to the winding course of the Forth, may be done at a very moderate expense, as I have formerly shewn in my report on the proposed canal from Forth to Clyde.

The very extensive trade up the river Aire and Calder in Yorkshire, which passes under Ferry Bridge, and of which coals is the principal article, is carried on in vessels of 56 feet long, stem and stern, 13 feet 6 inches wide, and drawing 3 feet water at a medium; in very dry times in summer they load 6 inches less, and in winter 6 inches more. These vessels at 3 feet draught of water carry, by reputation, from 20 to 25 tons, but of neat dead weight 28 tons; they are generally drawn by one horse, and make way nearly two miles an hour, stoppage at the locks included; though sometimes, for the sake of expedition, and when there are freshes in the river, and the vessels going against stream, they make use of two.

These vessels not only navigate in the narrow rivers, but go round into the Trent to Gainsborough and Newark, and frequently down the Humber to Hull. This sort of vessel, I apprehend, by the same rule, would not only go down to Alloa, and deliver their cargoes there on board ships, but would occasionally go into the Carron, and through the great canal, in case the same should take effect.

By this means, if a large ship meets with contrary winds, or comes in at such a time as to expect being neaped at the Cambus, she may be loaded at Alloa from the boats, in the same manner as all the ships at Newcastle and Sunderland are loaded from the keels there, which carry 21 tons each: on the other hand, when there are no ships that want loading at Alloa, or they happen to be brought down faster, then they are shipped at the Cambus, or sent away in the same bottoms to other places up or down the Forth, they then will be deposited in the coal-yard at Cambus, ready for the vessels that come up thither for a loading.

The dimensions of the Calder cuts for the vessels above described were, 16 feet bottom, the sides sloped 5 feet for 3 feet of perpendicular, and carrying $3\frac{1}{2}$ feet of water: now in carrying canals upon a dead level on the decline of hills, the ground is seldom so free from irregularities, but that it requires extra cutting in some places, and extra banking in others, which, as it would be impossible to determine exactly before the execution, as every variation, though but for a few yards, would vary the dimensions, must be allowed for, according to the judgment of the artist: to make allowance, therefore, for the common inequalities of ground in the present case, I compute upon a cut of 6 feet deep, that is, supposing the water $2\frac{1}{2}$ feet within soil; not that I expect it to be so in the general; but as in many places the extra cutting will be considerably more, and the deficiencies remain to be made good by so much labour, I make that supposition in order to come at the mean value.

Upon these general dimensions I have computed the expense, upon a supposition of an entire canal, except where it is proposed to come into the river, for the sake of crossing the same, to get the eligible ground, which amounts to the sum of 9357*l.*

2d. Supposing the river to be made use of in the general from Tillibodie Bridge to Sauchie new engine, with short cuts to take off loops and place the locks, in this case, though far less apparent work, yet as the disadvantage of placing the locks, as well as of constructing them, and laying their foundation below the level of the river, as it will require a lock more, a greater price for each lock, a greater depth of cut, and, on account of greater depth, as well as drainage of water, a greater price per yard of digging; I say, all those being allowed and computed, as in my judgment they ought to be, according to the following estimate thereof, this will make the whole stretch from Tillibodie Bridge to the elbow of the river above Sauchie old engine, near Tillicoutery Burnfoot, to amount to 4793*l.*; whereas, if done by canal, according to the first supposition, it will cost 5183*l.*, the difference being 390*l.* in favour of the river navigation: but if it be considered, that following the river increases the length near 1½ mile in 6½ miles, and that the works themselves will be perpetually in greater hazard from floods, and need more repair, this difference does not appear to be worth the saving.

As I observed the ground very capable thereof, I have computed the value of two miles of canal, which I suppose, if turned southwards a little below Menstrie Bridge, will carry it to Alloa: this is done upon a supposition of 40*l.* an acre for the land, which I apprehend to be very valuable in that district, the rest of the dimensions and prices as per first supposition; this will cost the sum of 2408*l.* This supposes a lock into Forth, but being nearly the same as that at Cambus, the only addition is in the canal.

Respecting the prices of land, I would be understood once for all, that I don't in these estimates by any means propose to fix a value upon it, as being an affair quite out of my province; but when different schemes are to be compared together, some value must be affixed to each of the component parts, in order to bring them to a comparison; for the cuts upon the valley of the Devon I suppose 20*l.* per acre average price, though I am very sensible that some of the grounds through which the cuts will pass, are more than ten times the value that others are; but as I apprehend the whole of the supposed cut from near Menstrie Bridge to Alloa, will pass through grounds as valuable as the best in the Devon valley, the comparison would in no respect hold, unless an addition was made to those supposed for the Alloa cut.

I now come to the article of water, and for this purpose particularly observed the new mill at Tillibodie, which is situated upon the river Devon, and enjoys the whole stream thereof; its water is penned by the same dam, from whence the cut is proposed to be taken to Cambus Quay. This mill, when going at its common rate, requires the sluice to be drawn up 11 inches upon a breadth of 3 feet, there being then a depth of water upon the sole of 25 inches.

Having hence computed the quantity of water expended when the mill was going at this rate, it comes out to be 1180 cube feet per minute. A lock required to carry vessels of the size above specified, will require to be 62 feet long, and 14 feet wide, whose area upon each foot in depth will be 868 feet; and supposing a lock to be of 6 feet pen, this will require 5206 cube feet to fill it, and the passage of each boat will require this quantity, unless two boats should meet together at a lock, one going up, and the other down, they then will both pass with one lock-full; but as this does not always happen, I generally reckon upon a lock-full to each boat, the savings of water upon

the aforesaid circumstance going in aid of the loss of water at the locks by leakage. Now the contents of a lock 5206 cube feet, being divided by 1180 cube feet expended at Tillibodie Mill per minute, gives 4 $\frac{4}{10}$ minutes for the time in which the said mill expends a lock-full of water of 6 feet high.

Again, if we supposed 10 boats to pass in a day, that is, 5 up and 5 down, we may very well suppose that out of these 2 may meet at or within sight of the lock; and if so, a lock-full of water will be saved, which I esteem equal to the daily leakage of a well-made lock; but however, to make an ample allowance for loss of water, not only by leakage, but by evaporation and accidents in dry weather, I will further allow 4 locks-full per day; the total expenditure will then be 14 locks-full, which will be equivalent to 61·6 minutes, or 1^h 1′ 42″; and this will be the time that Tillibodie new mill singly, and the two miles at the Cambus conjointly, will lose in 24 hours in the driest season; for at all other times, when the water runs waste over the dams, the navigation will not lessen the time of the mills working.

By information of the miller, there is in summer scarcely half the above quantity of water in dry seasons; that is, they can scarcely go at that rate above 12 hours in 24; hence, the navigation, circumstanced as before mentioned, will consume about $\frac{1}{11}$ part of the water that now goes to the mills in dry seasons; or, dividing the whole quantity into 11 parts, the mills will get 10 and the navigation 1; but, upon my view, it appeared, that Tillibodie new dam was considerably leaky, insomuch that it is probable that in dry times as much water goes through the dam as goes to the mill: this will be the case if the leakage is only half the mill stream when working; for one being constant, and the going but for half time, they will be equivalent to each other; but, as it may be necessary to make some alterations in the dam of Tillibodie new mill, if this is rendered water-tight at the expense of the navigation, this mill will be a gainer and not a loser by the navigation. The Cambus mills, however, which are situated upon the same river, and take their water from the new mill of Tillibodie, and receive also the leakage from that dam, will not be compensated by that alteration; but as both the mills at Cambus work from one head of water, the loss to them both will be no greater than was estimated for Tillibodie mill singly; but the loss to neither of those sets of mills will take place, as to the lockage, except for such vessels as go down into the Firth; for all such vessels as deliver their cargo into the yard at the Cambus for shipping, which may be expected to be far the greatest part, will expend no more water from Tillibodie or Cambus mills.

It is true that, according to the different states of the tide, a perpendicular height might be wanted greater than six feet; but as it will be often less, I suppose the one may nearly balance the other.

It would render the affair of the mills entirely free from compensations if a stream could be turned into the Devon, that now goes into some other river, equivalent to what will supply the navigation, which, from my view in passing through the country near the head of the Devon, does not seem difficult to do.

However, upon the whole, it appears, that even in an extended view, the quantity of water that will be used by the navigation will bear but a small proportion to the currency of the river Devon, even in the driest seasons; and as a ground-work for a compensation, in case an equivalent quantity of water cannot be brought into the Devon, it appears that for every 5206 cube feet of water that is drawn out of each head, at such times when the respective mills can use the whole, a sum equal in value to 4 $\frac{4}{10}$ minutes' work of such respective mills will be payable to the tenant or occupier of such mill or mills, he continuing to pay the same rent as before.

Now, exclusive of Sauchie engine, which will be proportionably affected with the rest, there are only three heads of water that will be affected, viz. the Cambus mills, which are corn-mills; Tillibodie new mill, which is also a corn-mill; and the mill above Tillibodie Bridge, which is a lint-mill; which, in proportion to the value of its time, will be affected in much about the same manner.

I make no account of soakage, because this, after the canals are seasoned, will be very trifling, and the greatest part will return into the river above the principal mills.

Austhorpe, September 14, 1767. J. SMEATON.

P.S. In regard to the scheme that has occurred to Messrs. Mackell and Watt, since I was upon the place, of carrying a canal upon a dead level from Tillicoutery to a point opposite the schoolmaster's house at Alloa, following the foot of the rising grounds the whole way, and which will be about 30 feet higher than the sea, proposing to continue the same from thence between banks across the flat ground to the waterside (which is not far), or making a cut through the flat grounds to the dead level termination of the canal, which plan would save locks and waste of water, I can only say that, from my view of the country, I believe such a project practicable; but, as I have neither plans nor sections of the course that it would take, I am in no capacity to judge of the expense.

It is obvious that this canal would be defective in not suffering the vessels to pass into the Forth, and that either the banking across the valley, which would be a considerable height, or digging across it, which would be a considerable depth, would be a considerable article of expense; and that in any view of the affair, if a communication with the Forth is dispensed with, a considerable saving may be made, but I apprehend not above one-third, between carrying vessels to navigate the Forth as above specified, and those the most curtailed that can any ways answer in point of quantity.

J. S.

ESTIMATE

For making a Navigation through the Valley of the River Devon from the Cambus to Mellock Glen Foot, supposed chiefly by a Canal.

	£.	s.	d.
To widening and deepening the old cut from the Cambus into Tillibodie new mill-dam, which, from the depth of the ground, I estimate as a new cut, the width at bottom being 16 feet, mean width at top, 36 feet; mean depth, 6 feet; at 3*d.* per yard, will come to 47*l.* 13*s.* 4*d.* per furlong, the length being 4½ furlongs,	214	10	0
To 1 lock from the cut into the tidesway	600	0	0
To 6·14 acres of land, if purchased at 20*l.* per acre	122	16	0
To 1 cart-bridge for communicating with the land cut	40	0	0
To repairing Tillibodie new mill-dam, so as to render the same more nearly water-tight	200	0	0
To extra cutting for passing-places, &c.	27	0	0
To extra land for ditto	15	0	0
From Cambus Quay to Tillibodie Bridge	1219	6	0
To clearing up and deepening the river from Tillibodie Dam, through the bridge, to the tail of the next cut	50	0	0
To cutting 3 miles 1 furlong of entire cut, of the dimensions above specified, from Tillibodie Bridge to Sauchie new engine, that is, 25 furlongs, at 47*l.* 13*s.* 4*d.*	1191	13	0
Carried over	1241	13	0

	£.	s.	d.
Brought over	1241	13	0
To 34·1 acres of land, if purchased at 20*l.* at a medium	682	0	0
To a road-bridge over the cut, answerable to Menstrie Bridge, with a stone arch	80	0	0
To three cart-bridges to preserve the roads and communications between lands, from the above to Sauchie new engine	120	0	0
To extra cutting for passing-places, &c.	149	0	0
To extra land for ditto	85	0	0
To digging a cut from Sauchie new engine to the elbow of the river near Tillicoutery Burn Foot, being in length 1 mile, or 8 furlongs, at 47*l.* 13*s.* 4*d.* per furlong	381	7	0
To 10·91 acres of land, at 20*l.*	218	4	0
To 2 cart-bridges over this cut	80	0	0
To 3 locks upon this district, at 500*l.* each	1500	0	0
To extra cutting for passing-places, &c.	48	0	0
To extra land for ditto	27	0	0
To extra expense in cutting through the rising ground at the Coble Crook	100	0	0
From Tillibodie Bridge to the head of Sauchie Gut	4712	4	0
To raising a dam to pen about 7 feet water in the elbow of the river next above Sauchie old engine, near the foot of Tillicoutery Burn	500	0	0
To embanking the flat ground adjacent to the river Devon, on the north side from the said dam upwards, so as to be flood-proof, supposing it, at a medium, to be ¼ of a mile in length, 6 feet height, 6 feet top, and 24 feet base, this will contain 4400 yards, ramming and sodding or turfing included, at 4*d.*	73	7	0
To 1½ acres of land, that will be cut and covered by this work	30	0	0
To extra expense in securing the land near the foot of the dam, and in guarding the same from the effects of Tillicoutery Burn, suppose	100	0	0
Expense of continuing the navigation half a mile up the river Devon, from the head of the Sauchie Cut to the tail of the cut near the bridge of Tillicoutery	703	7	0
To widening or making a new cut past the bridge of Tillicoutery, from the dam into the river below the tunnel wherein the engine water crosses the same, being in length 2 furlongs, at 47*l.* 13*s.* 4*d.* per furlong	95	7	0
The land cut and covered will contain 2·73 acres, which, at 20*l.* an acre, comes to	54	12	0
To a lock upon the said cut	500	0	0
To a road-bridge over the said cut, answerable to Tillicoutery Bridge	80	0	0
The cut, &c. to pass by Tillicoutery Bridge into Tillicoutery Dam	729	19	0
To cutting across the flat grounds from the first elbow of the river above Tillicoutery dam to Mellock Glen Foot, being in length 5½ furlongs, at 47*l.* 13*s.* 4*d.*	262	3	0
The land cut and covered 7·5 acres, at 20*l.* per acre	150	0	0
To a lock upon the said canal	500	0	0
Two cart-bridges for preserving communications	80	0	0
To extra cutting for passing-places, &c.	33	0	0
To extra land for ditto	19	0	0
To carrying the navigation from Tillicoutery Dam to Mellock Glen Foot	1044	3	0

SUMMARY OF THE ESTIMATE

For making a Navigation through the Valley of the River Devon, from the Cambus to Mellock Foot, supposed chiefly by Canals.

From Cambus Quay to Tillibodie Bridge	1219	6	0
From Tillibodie Bridge to the head of Sauchie Cut, at the elbow of the river above the old engine at Sauchie, and near Tillicoutery Burn Foot	4712	4	0
From thence, through the river, to the foot of the cut that passes Tillicoutery Bridge	703	7	0
Carried over	6634	17	0

	£.	s.	d.
Brought over	6684	17	0
The cut to pass by Tillicoutery Bridge into Tillicoutery Dam	729	19	0
From Tillicoutery Dam to Mellock Glen Foot	1044	3	0
To 6½ miles of towing-path, which, with towing-bridges, gates, stiles, back drains, &c. is supposed to cost 15*l.* per mile	97	10	0
	8506	9	0
Add 10 per cent, for unforeseen accidents and expenses not included in the foregoing stimate	850	12	0
	9357	1	0

ESTIMATE.

To shew the Difference between keeping the River as much as possible from Tillibodie Dam to Sauchie new Engine, and the entire Canal before proposed.

To clearing up and deepening Tillibodie Dam, through Tillibodie Bridge, to the tail of the cut, as before	50	0	0
To cutting from Tillibodie Bridge into the Lint Mill Dam, being in length 4 furlongs, and which, passing through deeper grounds than if carried upon a dead level, may be supposed 7 feet mean depth, which, with bottom and slopes as before, will contain 18,164 yards, and which, being deeper, and partly under level of the river, so as to require artificial drainage, I reckon at 4*d.* per yard	319	8	0
The ground cut and covered will be, at a medium, 100 feet wide, and, therefore, 4 furlongs will contain 6·06 acres, which, at 20*l.* an acre, comes to	121	4	0
A lock upon ditto requiring drainage, and to be built higher than if upon a dead cut	550	0	0
A cart bridge over the cut for communication	40	0	0
The work to pass the Lint Mill above Tillibodie Bridge	1080	12	0
To making a cut at the letter A, of 1 furlong of dimensions, as the former, will contain 4791 yards, at 4*d.*	79	17	0
The cut and cover will contain 1·51 acres, which, at 20*l.*, comes to	30	2	0
A lock upon the cut, as before	550	0	0
A cart-bridge over the lock for communication to the island	15	0	0
A dam to pen the water	300	0	0
Cut, &c. at the letter A.	974	19	0
To making a similar work at B, which will carry the navigation to Sauchie new engine	974	19	0
To 1 mile of cut, from Sauchie new engine to the elbow of the river near Tillicoutery Burn Foot, as per former estimate	381	7	0
The land for ditto, as before	218	4	0
To two cart-bridges, as before	80	0	0
To a lock from the cut into the river	550	0	0
To extra cutting for passing-places, &c. as before	48	0	0
To extra land for ditto, as before	27	0	0
Cut from Sauchie new engine to Tillicoutery Burn Foot	1304	11	0

SUMMARY OF THE FOREGOING ESTIMATE.

Cut from Tillibodie Bridge into Lint Mill Dam	1080	12	0
Cut, &c. at the letter A	974	19	0
Ditto, at B	974	19	0
Cut from Sauchie new engine to Tillicoutery Burn Foot	1304	11	0
Increase of hawling track 1½ mile, at 15*l.*	22	10	0
From Tillibodie Dam to Sauchie Cut, by keeping as much as possible the course of the river	4357	11	0
Carried over	4357	11	0

				£.	s.	d.
			Brought over	4357	11	0
Contingencies, at 10 per cent				435	14	0
				4793	5	0
By an entire canal, as before	£.	4712	4 0			
Contingencies, at 10 per cent		471	4 0	5183	8	0
Difference of expense in favour of the river navigation				390	3	0

ESTIMATE FOR CONTINUING THE NAVIGATION, BY CANAL, TO OR NEAR ALLOA.

If, instead of dropping the cut into the river just above Tillibodie Bridge, the level be preserved from the Coble Crook, and turned from near Menstrie Bridge towards Alloa, the increase of distance, according to plan, will be about 2 miles.

	£.	s.	d.
To 2 miles of cut, at 47*l.* 13*s.* 4*d.*	762	13	0
To 21·82 acres of land, at 40*l.* per acre	872	16	0
Suppose 2 road-bridges, at 80*l.*	160	0	0
To 4 cart-bridges, at 40*l.*	160	0	0
To 2 miles of hawling track, at 15*l.*	30	0	0
To extra cutting for passing places, &c.	95	0	0
To extra land for ditto	109	0	0
	2189	9	0
Ten per cent for unforeseen events, &c.	219	0	0
Addition, to carry the cut to Alloa	2408	9	0

Austhorpe, September 14, 1767. J. SMEATON.

Lord Cathcart's Queries of the 11th of September, 1767.

To Mr. Smeaton, from Lord Cathcart, September 11, 1767.

In winter the freshes and quantities of ice are so great, that it is difficult for ships to lie in the Forth; they are obliged in that season to shelter themselves in what is called the Pow of Alloa; they cannot go up to Cambus, nor can boats come down, which would prevent a constant intercourse between the Devon collieries and the ships in the Forth, supposing the navigation to be made partly in the Devon, and partly in cuts from Tillicoutery to Cambus, where it joins the Forth.

There is another method which would be certain and constant,* except when the canal was frozen, and is as follows:—Suppose Lord Cathcart's aqueduct were to be widened to the proper size, from the pipes at Tillicoutery, to the new engine at Sauchie, and from thence carried on upon the same level to the west end of the

* Since writing, I have been informed, that the water drawn from the pits, with which the canal before mentioned would be filled, never freezes.

town of Alloa, it would finish upon a bank about 15 feet higher than the pier of Alloa, and about 300 yards distant from it; from this dead water canal a branch may be carried off, which will be very short, and which will terminate equally on a bank near the Forth, a little below the mouth of the Devon, from both which banks the coals may be conveyed in waggons to the sides of the ships at Alloa, or boats at Cambus, which come down the Forth from the upper parts of the river.

In this plan there are the following advantages:

There will be no locks; there will be no waste of water, which will be particularly agreeable to some proprietors principally concerned.

The boats may be contracted in width and increased in length, and may be very flat, and, consequently, the canal much shallower and narrower than if it were to carry boats fit to navigate the Devon or Forth.

And for these reasons it is supposed the navigation may be executed cheaper, and with more certainty than in any other method, and may, in the same manner, be carried up the river, as far as proprietors please, on the north bank, although on the upper part there will be a necessity to have some locks, as it must be on a higher level than the under.

Query 1st. Were such a canal to be executed, what would be the proper dimensions of it, and of the boats, and what would be their burden?

Query 2d, Would there be any difficulty in carrying such a canal over rough ground about Cobble Brook, or any danger that it should penetrate into the waste of the Alloa coal over which it must pass, or that by any little falling in of that waste, which now and then may happen, the canal may be lost?

N.B. The waste is 20 fathoms below the surface, and there are collieries which do not lie deeper, and are wrought under the sea without inconveniency; but as this danger struck the proprietor, it is thought proper to ask the question.

Query 3d. How much per mile ought such a canal at an average to cost?

ANSWER

To Lord CATHCART'S *Queries of the* 11*th of September,* 1767.

To query 1st. THE boats proper in my opinion for a small canal, is not to make them of extraordinary length, but to make them go in pairs; the sternmost boat serving as a rudder to the headmost boat, which not only gives them a very great advantage in turning, but by keeping them short renders them much stiffer, and consequently subject to less wear and tear.

This method is practised in all the rivers and canals communicating with the great levels of the fens of Lincolnshire, Cambridgeshire, Norfolk, &c. where they sometimes go in gangs of four, five, six, sometimes seven, in a string, and where the second boat, steering the first, is followed by all the rest in the same curve; their burden is from 15 tons to 5.

I cannot, however, recommend so many of them for your purpose, as your voyages will be shorter, the returns quicker, will be managed with fewer men and horses, and in a very narrow canal more easily directed.

The dimensions I would recommend for your use are as follows:

		Ft.	In.	
The head boat	Extreme length	38	0	Burden 12 tons
	Extreme breadth	9	0	
	Draught of water loaded	2	6	
The stern boat	Extreme length	36	0	Burden 10 tons.
	Extreme breadth	9	0	
	Draught of water loaded	2	4	

These two boats will be drawn with one horse from 2 to 2½ miles per hour, and will be managed by one man on board.

A canal proper for such boats, so as to suffer them to draw freely, should be 12 feet bottom, with 3 feet depth of water; the width of the water-line will vary according to the batters; but supposing those at a medium to be 3 to 5, and the surface at a medium 2 feet within soil, the ordinary expense per mile, at 3*d.* per yard, will be 242*l.* and the quantities of ground, including cut and cover per mile, will be about 6 acres, English measure.

Where great hollows are to be filled, or hills to be cut, the extra expenses thereof are to be further allowed, as all the charges of aqueduct and common bridges, tunnels, back-drains, towing-paths, &c. to be added; also allowance made for passing-places, turning-places, &c., which may in a great measure be judged of by my report and estimate already delivered on the subject of the river Devon, but cannot be more particular at present, for want of plans, sections, and time.

To query 2d. I do not apprehend any extraordinary difficulty with the rough ground about Cobble Crook, more than what happens in like cases. As to danger from the falling in of the old wastes of the Alloa coal, I do not apprehend they can affect the canal, or the canal affect them, unless there happens a fail immediately under the canal which reaches the surface; in this case, the water of the canal will undoubtedly make its way down into the waste; but if steps are constructed at proper places, as is done in the Duke of BRIDGEWATER's canals, no great quantity can go down, and the breach may be repaired so as to be water-tight as at first: but if wastes of collieries are supported like those which are worked under the sea, and are not used to fall in so far as the surface, I can see no reason for this apprehension.

AUSTHORPE, 8th October, 1767. J. SMEATON.

P.S. I do not know that it is a property of coal-pit water *not to freeze:* it is certain that the water from all mines comes out of the earth at about the forty-eighth degree of FAHRENHEIT's scale of heat, it must, therefore, remain unfrozen till by the superior cold of the external air, and surface of the earth, it is reduced to thirty-two degrees of the same scale. If it has any property by which it remains unfrozen, after its heat is reduced below that degree, it is a peculiarity I am unacquainted with.

MEMORIAL AND QUERIES

Relative to Mr. SMEATON's Report of the Navigation of the Devon, of the 14th of September, 1767: from Lord CATHCART, the 14th of March, 1768.

MR. SMEATON, in his Report of the Devon Navigation, dated September the 14th, 1767, lays down the following proposition.

That the navigation may be carried up from the Forth at Cambus to old Sauchie, by two methods, which he describes and estimates, by making a canal the whole way from Tillibodie Bridge to Sauchie, or by making a cut from Tillibodie Bridge to Minstrie Lint mill-dam, and making use of the bed of the river from thence to old Sauchie. Mr. SMEATON estimates the expense of this part of the navigation from the Forth to Sauchie in the first manner, that is, using the river as little as possible, at 5183*l.*, and in the second, that is, using the river as much as possible, at 4793*l.*; and though the former, according to his estimate, will cost 390*l.* more than the latter, he prefers and recommends it, for the following reasons, viz. because the distance will be shortened 1½ miles in 6½ miles, and because the works will be in less hazard from floods, and will require less repair.

The following considerations, in favour of the second method, are submitted to Mr. SMEATON, who, when he made his report, was under the disadvantage of being deprived of papers and memorandums relative to the levels, and other circumstances of the Devon.

1st. There is already 4½ feet of water in the Devon, from the Lint Mill as far up as Coble Crook Ford, so that the work at A, in Mr. SMEATON's plan, estimated at 975*l.*, being in water 9 feet deep, cannot be necessary, the price of it ought to be added to the balance in favour of the second method, and will raise it from 390*l.* to 1465*l.*, which is an object.

2ndly. From Coble Crook to Hennie's Burn, a convenient place for boats to lie in, a little below Sauchie new engine, there is a rise of no more than 3 feet 2 inches; at Coble Crook there is a foundation of rock, with rocky and steep banks on each side, and a very good quarry close to it, so that there seems no reason to believe a dam of 3 feet 2 inches high, and a lock of that rise, can possibly cost a sum, upon any principle of Mr. SMEATON's other calculations, equal or near equal to 975*l.*; but it may be proper to leave that article as it stands, because if the people of Alloa are cut off from Alloa, by the ford being destroyed by the dam, there will be a necessity to build a bridge over the Devon, probably at Sauchie, as there is a good foundation and a quarry at hand, which will cost 200*l.*: if so, the expense of the second method will remain 3818*l.*

3dly. If the first method is used, the expenditure of water from the Tillicoutery Dam, which supplies Sauchie engine, will be increased by the consumption of the Sauchie and Collyland coals, which in the second method would embark in the river above the Coble Crook dam, and would waste none of the water belonging to the Tillicoutery Dam; and it must be remembered that the Sauchie engine can on no account give up any water which it has or may have occasion for, and has at present a right to.

4thly. The greatest difficulty attending works now to be carried on in Scotland, will be the want of labourers. The execution of the second method will not require above one-sixth part of the labourers the first would require, because the digging is as ½ to 3, and the lockage as 3½ to 20.

5thly. As the Lint Mill and Tillibodie Mill Dams have been proof against the greatest floods, it may be presumed that the Coble Crook work, which is better placed, and will be better, will be equally safe, and will be a security to the works below.

Query 1st. Upon the whole of these considerations, does Mr. SMEATON admit the deduction of his work at A, and its expense 975*l.*? Does he recommend the canal from Sauchie to Tillibodie Bridge, or the river from Sauchie to the Lint Mill; and, if the latter, would he place the lock at Coble Crook; or at any situation above it, in which case the Coble Crook Ford must be deepened?

Proposition 2d. Mr. SMEATON proposes to carry up the navigation from Sauchie to Tillicoutery Burn Foot by canal; to raise the river by a dam to supply that canal; to cross the river and lock up into a cut on the north side and on the level of Tillicoutery Dam; to repass the river above Tillicoutery Dam and lock, up into a cut on the level of the tail-race of the Rack Mill, and in that cut to proceed to Mellock; and for these operations he makes the following charge:

	£.	s.	d.
From Sauchie New Engine to Tillicoutery Burn Foot	1304	11	0
From thence, through the river, to the next cut	703	7	0
Cut into Tillicoutery Dam	729	19	0
Cut from thence to Mellock Foot	1044	3	0
Towing Path, at 15*l.* per mile, for 2¼ miles	37	10	0
	£.3819	10	0

It is submitted to Mr. SMEATON, whether the following method would not be preferable, for the following reasons, viz.: To enlarge the Sauchie aqueduct to the size of a canal from the New Engine across the road leading to Tillicoutery Bridge; to carry it either on the same level as far as Mellock, being 2 miles and a half, and there raise it by a lock to a level of the tail-race of the Back Mill, and continue it from thence the space of 1 mile further to the tail-race of the said mill, or by placing the lock nearer Tillicoutery Bridge, and raising the level of the canal earlier, as may be thought most convenient.

1st. Because this work will be entirely out of the reach of the highest floods, and the works at Tillicoutery Burn Foot, the most precarious and expensive, in point of repairs, in the whole navigation, will be saved, and the price of it being 703*l.* will probably more than answer the extra expense of carrying a canal along the south bank of the river, betwixt Tillicoutery Bridge and Tillicoutery Dam, where the ground is more narrow and difficult, as well as the additional length of canal beyond Mr. SMEATON's calculation, amounting to 6 furlongs, which it is apprehended, will require less expense in digging and in land than the shorter place, which is proposed to run through ground much more valuable, and to be cut much deeper within soil, especially betwixt Sauchie and Tillicoutery Burn.

2d. Because by keeping the canal 20 feet above the level of the river at Hennie's Burn, it may be, with the same expense, communicated by locks at that point, as if the lockage had been dispersed along the whole course of it; and if either money or hands should fall short, the execution of these 20 feet of lockage might be postponed, and an immediate communication opened, for the time being, betwixt boats coming up the Devon, as far as Sauchie from the Forth, and boats coming down from the Rack Mill to Sauchie, till the junction is completed by locks.

3d. Because, by carrying up the navigation 1 mile beyond Mellock, no additional lockage will be incurred, as the lock necessary is marked in Mr. SMEATON's plan, and the expense included in his estimate; so that the additional expense will be no more than the digging, land-bridges, and towing-path of 1 mile, amounting, according to Mr. SMEATON's estimate, to 769*l.*; and the benefit of water carriage will be communicated to Dollar and the country above it, as there is now a bridge at the Rack Mill, and to the Blairngon Colliery, to which a road for the carriage of coal may easily be made; and it is supposed that the produce of that colliery, whether carried to the sea or to the north country, would go down the Devon, which would both increase its produce and raise its tolls.

Query 2d. Is Mr. SMEATON of opinion, that the navigation ought to be carried up to Mellock in the manner above described, keeping the south side of the water the whole way, and that the expense will not exceed the above estimate of

3819*l.* 10*s.*? That it ought also to be carried up to the Rack Mill; and that the additional expense will not exceed 769*l.*—in all 4588*l.* 10*s.*? To which, supposing 3818*l.* to be added, for the space betwixt Cambus and the Sauchie, the two sums will make 8406*l.* 10*s.*, and with 843*l.* 10*s.* for extraordinaries, the whole expense of the navigation from Cambus to the Rack Mill, for boats drawing 3 feet water, will amount to 9250*l.* according to the principles of Mr. SMEATON's estimate.

Query 3d. As the boats described by Mr. SMEATON, drawing 3 feet water, are only fit to go down the Forth, as far as Carron, with which the Devon, as both their produce in coal cannot have much intercourse, it is desirable that a foot of additional depth should be given to the works below Sauchie, in order that they may be passable for boats drawing 4 feet water, 13½ feet wide, 42 feet long, and carrying 25 tons; such boats being constructed in the Clyde, for the navigation of the highland seas, and, therefore, supposed fit to go to Leith, and in summer to the north country. Query, What additional expense would this alteration cost? It is supposed, that if a foot were to be added to the Lint Mill and Tillibodie Mill Dams, the river would still be within soil, and would require no banking; and, if so, that a foot more water would be thrown into the two cuts without any further expense for extra digging, and that in the river there is a sufficient depth.

Query 4th. What would be the expense per mile of deepening the canal 1 foot between Sauchie and the Rack Mill?

Query 5th. The ground being favourable for cutting a canal, on a dead level, from the Lint Dam to Stirling Bridge, where it might be communicated by a lock or locks of 11 feet fall with the Forth, it would be proper to include this circumstance in the act of Parliament, because not only all the coals for the north country sale would be conveyed by it to Stirling Bridge, but also the Upper Forth boats coming to the Devon for coals would lock up at Stirling Bridge, rather than Cambus, as they would save near 12 miles each trip; the expenditure of water would be diminished, rather than increased, because the lockage is not computed at more than one lock-full per day. The coals for the north country and for Stirling would waste no water, which they must do were they to go down the Devon and up the Forth, and the boats coming and going from and to Craigforth would waste the same water, whether they entered the canal at Stirling Bridge, or the Devon at Cambus. Mr. SMEATON estimates 2 miles of canal between Menstrie Bridge and Alloa, at 2400*l.*, and the lockage from the level of the former into the Forth of the latter, at 1100*l.*,—in all, 3500*l.* Query, The height being the same, and the distance one third greater, is not 4700*l.* an adequate price for the branch from the Lint Mill Dam to Stirling Bridge, being 3 miles in length, and for the lockage into the Forth? viz. together with the former sum of 9250*l.*, would make in all 13,950*l.* for the navigation of the Devon, and for the branch to Stirling.

PERTH BRIDGE.

Memorial for Mr. SMEATON.

August 1763.

THE Justices of Peace for the county of Perth, at their quarter sessions in May last, having entered into several resolutions to promote a scheme for building a bridge across Tay, at or near Perth, did, among others, appoint a committee of their number to meet with and consult Mr. SMEATON on this subject.

These gentlemen now take this opportunity of applying to Mr. SMEATON, that he will visit and inspect the river at and near the town of Perth, and report to them the proper place for erecting such a bridge, paying always a particular attention to the safety of the town of Perth and the adjacent grounds, as well as the bridge.

He will be pleased, at the same time, to consider how far a stable bridge, of any other materials than stone, can be constructed, so as to answer all the requisite purposes of carriages, &c., and be made more properly adapted to the situation and rapidity of the river, and safety of the town.

As Mr. SMEATON will satisfy himself as to the measures of the breadth of the river at the different places, it is only necessary to observe, that the land-floods often swell the river, with great rapidity, 14 feet higher than the water is in summer, and that the stream-tides flow to the height of 8 feet, or thereby, opposite to the North Key, where the former bridge was built, and that the bed of the river is generally hard gravel.

If Mr. SMEATON should approve of the scheme, and determine on the situation, it will be proper that, with conveniency, he make a plan of such bridge as he shall judge most eligible; for which plan, and his trouble in visiting the river, the committee will properly gratify him.

THE REPORT

Of JOHN SMEATON, Engineer, concerning the Practicability of building a Bridge over the River Tay, at Perth, in Answer to a Memorial thereupon addressed to his Consideration by the Committee of Justices, bearing date, August 1763.

HAVING, pursuant to my instructions contained in the said memorial, examined the soundings of the river Tay, at and near the town of Perth, in the month of August last, as well as other circumstances relative thereto, I am of opinion as follows.

1st. That from the rapidity of the river, and the quantity of ice, said to come down the same in winter, that though a bridge may be built of timber sufficient to answer the purpose for a number of years, yet, to give the same the necessary degree of stability, will, in its first direction, be near as expensive as if built with stone, and, from the perishableness of the materials, be subject, in the course of a few years, to great and expensive repairs; and, withal, considering that this is a part of the country where good workable and durable stone is cheap, and good oak timber dear, I can by no means recommend a bridge of any other materials than of stone.

2d. I am of opinion, that it is practicable to build a durable and useful stone bridge at or near the town of Perth, and without any danger or hazard to the town likely to arise therefrom, provided it be constructed with a sufficiency of water-way.

3d. I am of opinion, that two of the most proper places for the situation of a stone bridge is either in a right line with the Town Street, nearly where the old bridge* was erected, or a little above the town, from the Tenter in the North Inch to the opposite shore in James Bissett's garden.

4th. Of these two places, I prefer the latter, on account of less difficulty and less expense; for though the river is wider at the latter situation than at the former; yet, as the depth is considerably less, the expense and hazard of making coffer-dams

* Built by JOHN MYLNE, and swept away (in 1621) by a mighty inundation.

for laying the foundation of the piers, will be very considerably greater opposite the town than at the North Inch; and the expense of making dams, and clearing the foundation will be further enhanced by the remainder of the old piers, all or most of whose foundations probably remain in the river.

5th. In consequence of this preference, I have made a design for a stone bridge to be erected from the Tenter at the North Inch to the opposite shore, which accompanies this report, and have also annexed an estimate of the expense; the width of the river here I make to be about 653 feet.

6th. It is to be remarked, that it appeared to me, from sounding, that the bed of the river was everywhere a firm gravel, sufficient to support the weight of such a bridge as I have proposed; but from information I learnt, that, in digging near the river, there is everywhere a stratum of sandy clay, lying about 4 feet under the bed of the river, and about 4 feet thick: now, as some excavation in the bed of the river will be necessary, this will reduce the upper crust of gravel so thin, that the stratum of sandy clay, being of a yielding nature, the bridge cannot, with safety, be trusted upon it without piling, nor even with piling so securely; nor can it be done at so small an expense as by carrying the foundation down to the surface of the under-bed of gravel, which is said to reach to an unknown depth. For these reasons, I have supposed the foundation of the bridge to be laid 8 feet under the bottom of the deepest part of the river, where the bridge is proposed to be fixed, and have estimated the expense accordingly; but if it should turn out, on boring or digging, that the upper stratum of gravel is considerably *thicker* than here supposed, or that no such stratum of sandy clay subsists at this place, then a considerable expense will be saved, the foundation being here supposed to be laid 10 feet under the surface of the river at low water in dry seasons. On this account, I would advise the foundations to be tried before any thing definitive be determined.

7th. It is to be further remarked, that the prices in the following estimate are such as are usual for such kind of work in this part of the kingdom, and such as I apprehend it may be done for at Perth; but, for further satisfaction, if the committee please to order my estimate to be drawn out, with the quantities there inserted, without the prices, they will have an opportunity of having the sentiments of the workmen of the country thereupon, by causing them to fill up the same; only regarding the coffer-dams, as the method therein proposed cannot be explained without models, nor indeed successfully practised, but by a person experienced therein; their sense thereupon will be best had, by stating the internal circumference of the dams, and that they are, at a medium, to pen out 6 feet water: the committee will thereby come at the cost thereof in such method as the workmen themselves would propose; but, as the method is put in daily practice here, the committee may depend on its being practicable, and at the prices stated, unless there is a material difference in the value of timber and labour here and at Perth.

ESTIMATE FOR ERECTING

A STONE BRIDGE OVER THE RIVER TAY, AT PERTH,

From the Tender at the North Inch to the opposite Shore; to have 7 principal Arches, extending 605 *feet* 9 *inches, and in the whole length,* 893 *feet; to be* 22 *feet in the clear, within the parapets, and to have a walking path on the south side of* 4 *feet wide.* *By* JOHN SMEATON.

COFFER DAMS.

THERE being, according to my information, a stratum of hard gravel at the depth of 8 feet below the bed of the river, I propose to found the piers immediately thereupon, without piles or grating; and in order to come at this foundation, as the river will not in its low state be above 2 feet deep of water, and does not rise at ordinary spring tides more than 8 feet above this mark, and at neap tides little worth regarding, I reckon that a dam capable of holding out the water 4 feet above its low state, will enable the workmen to work nine or ten days successively between each spring tide; and I apprehend a dam of this height will not only be constructed at a much less expense, but be less subject to hazard, than if raised so as to pen out the spring tides; this dam to have a sluice upon it, to let the water in and out, as occasion shall require; and, for the more safe and ready excavation of the matter, I propose the dam to be placed at a medium 16 feet distant from the base of the pier, and to be of an elliptical figure, the better to resist the tides and floods.

	£.	s.	d.	£.	s.	d.
To 26 gage piles, of 10 feet long, at 10*s.* each	13	0	0			
To 2328 feet superficial of plank piling, 9½ feet long, at 1*s.* 2*d.*	135	16	0			
To 122 cube feet of timber, in string pieces, for supporting the pile heads, at 3*s.*	18	6	0			
To extra work, in making a sluice for letting the water in and out	2	10	0			
To timber work in one coffer dam				169	12*	0
To pile shoes, for 26 gage piles, at 1*s.* each	1	6	0			
To plank pile shoeing, 245 running, at 6*d.*	6	2	6			
To 25 bolts for the string pieces, at 2*s.* each	2	10	0			
To extra iron-work about the shuttle, and contingencies	2	0	0			
To iron-work about one coffer dam				11	18	6
A coffer dam complete				181	10	6
The materials for the first pier are supposed to be of half value toward each succeeding pier, which will therefore be No. 6. at 90*l.* 15*s.* 3*d.* each				544	11	6
Coffer dams for the whole				726	2	0

EXCAVATION AND DRAINAGE.

To excavation of the matter 722 yards, at 6*d.* comes to, each pier	18	1	0			
To drainage of the water, supposed equal to 50 days, at 20*s.* per day, per pier	50	0	0			
	68	1	0			
To excavation and drainage of 6 piers, the 2 abutment piers, and foundation for the wing walls, being supposed equivalent to 2 piers, the whole will be equivalent to 8 piers, at 68*l.* 1*s.* each				544	8	0

* In the estimate delivered in, this number was, by mistake called 2 instead of 12*s.* and the dependent sums being less accordingly, made the articles of the coffer dams be 724*l.* 2*s.* instead of 726*l.* 2*s.*

MASONRY IN THE PIERS AND ABUTMENTS BELOW THE SPRINGING OF THE ARCHES.

	£.	s.	d.	£.	s.	d.
To 1080 feet superficial of ashler in each pier below water, at 7*d.* ..	31	10	0			
To 1176 ditto above water, at 8*d.*	39	4	0			
The whole pier, in solid, contains 467 cube yards, including labour, carriage, tarras mortar 6 inches in the outside joints, and all materials, at 5*s.* per yard	116	15	0			
N.B. The ashler being at least 20 inches bed, and cubed into the solid, at 5*s.* per yard, is supposed to pay for the tarras mortar and extra labour in setting thereof.						
To capping the pier with solid blocks jointed between the springer stones, 600 cube feet, at 6*d.*.....	15	0	0			
To capping the ends of the piers 148 feet superficial, at 8*d.*	4	18	8			
To 6 piers, and 2 abutment piers, each reckoned as a pier, that is No. 8, at 207*l.* 7*s.* 8*d.*	1659	1	4			
To walling-in the west land stool to bring it up to the springers, to be at a medium 5 feet thick, containing 490 cube yards, at 5*s.*	122	10	0			
To hammer-dressing that part of the wall that comes in view below the plinth, containing 666 feet superficial, at 1½.....	4	3	3			
To working the plinth, being before reckoned as solid, containing 990 feet superficial, at 3*d.*.....	12	7	6			
To 78 cube yards of masonry in the east land stool, to bring it up to the height of the springers, at 5*s.*.....	19	10	0			
To setting under the west abutment arch to prevent the water from affecting the foundations, 1353 feet, at 4*d.*	22	11	0			
Masonry in the piers and abutments below the springing of the arches				1840	3	1

CENTERING FOR THE ARCHES.

		£.	s.	d.	£.	s.	d.
To timber in one rib, 416 cube feet, and for 6 ribs	2496 cube feet.						
To timber in 30 bearing piles, and 5 capt-trees for supporting the ribs	750						
To stays and bracings between the ribs to keep them upright	75						
To covering for the centres in square scantlings	525						
To additional work to make the centres fit the larger arches	188						
To timber in a centre complete, at 3*s.* per foot	4034			605	2	0	
To iron-work in the six ribs, 1852lb. at 5*d.*		38	11	8			
To ditto in pile-shoes and hoops, 662lb. at 5*d.*		13	15	10			
To spikes, nails, and other contingent articles		5	0	0			
To iron-work for one centre					57	7	6
To one centre complete.....							662	9	6
To a set of piles and cap-pieces ready prepared for driving in the second arch before the first centre is struck, containing 750 feet, at 2*s.*.....							75	0	0
To 5 booms, containing 375 feet of timber, at 2*s.* to be fixed as struts between the piers of the second arch, while the centre is taking down from the first, and putting up in the second.....							37	10	0
To taking down the centre, drawing the piles, driving ditto, and setting up the centre six times, repairing and making good what is wanting, at 9*d.* per foot solid upon the timber, which being 4034 feet, comes to 151*l.* 5*s.* 6*d.* each time, and for six times ..							907	13	0
To taking down and putting up the booms five times, at 6*d.* per foot							46	17	6
To centering for one of the small arches, at 1*l.* per square.....							20	0	0
To taking down, removing, and setting-up ditto in the other arch.....							5	0	0
Centering for the bridge, complete							1754	10	0

MASONRY IN THE SUPERSTRUCTURE.

	£.	s.	d.
To 15,850 feet superficial in the soffite of the main arches, being three feet thick, set in place, and mortar included, at 20*d.*	1320	16	8
To 2000 feet superficial in the soffite of the abutment arches, at 12*d.*	100	0	0
To blocking up the spandrils of the arches solid, 6 feet high, containing 473 cube yards, at 5*s.*	118	5	0
To cube masonry in the spandril walls, abutments, and wing walls, from the top of the piers to the top of the cordon, containing 3776 yards, at 5*s.*	944	0	0
To hammer-dressing the plain superficies thereof, containing 33,984 feet, at 1½*d.*	212	8	0
In the parapet 11,856 feet superficial on both sides, being 15 inches thick, stone, workmanship, mortar, and setting ditto, at 6*d.*	269	8	0
To 18,382 feet superficial in the faces of the arches, bands, and keys, the cordon, mutules, capping, and pedestals, which being before reckoned in solid, except their projecting parts and all square work, I put at 4*d.* per foot	306	7	4
To 2160 feet superficial in the 12 eyes, and 640 feet in the terminating pillars, in the whole 2800 feet superficial of circular work (being before included in the solid) at 6*d.*	70	0	0
The walking-path, being 4 feet wide, contains 3641 feet superficial, stone, working, and laying, at 7*d.*	106	12	0
Masonry in the superstructure	3447	17	0

GRAVEL.

To 10,948 cube yards of gravel to fit up the spandrils and wing walls, and form the road, at 9*d.* per yard	410	11	0

N.B. No part of the road is considered except what falls within the walls of the bridge.

CONTINGENCIES.

To piling engines, pumps, and other utensils, supervisal, unforeseen accidents and expenses	1000	0	0

ABSTRACT.

To coffer dams	726	2	0
Excavation and drainage	544	8	0
Masonry in the piers and abutments below the springing of the arches	1840	3	1
Centering for the arches	1754	10	0
Masonry in the superstructure	3447	17	0
Gravelling the bridge	410	11	0
Contingencies	1000	0	0
Total, £.	9723	11	1

N.B. In the batterdeaus and centres there will remain at least 5763 cube feet of timber, which, if sold for 9*d.* a foot cubic, will amount to 214*l.* 2*s.* 3*d.* besides ironwork, engines, and utensils, which, it is presumed, will be sufficient to make the road to and from the bridge.

The prices in the preceding estimate include all labour, carriage, mortar, and setting-up in place, unless otherwise particularly expressed.

EXTRACT

Minutes of the Trustees for Building a Bridge over the Tay at Perth.

At Perth, the 26th day of September, 1765 years, at a meeting of the trustees for building a bridge over Tay, at Perth, four letters from Mr. Smeaton to the Earl of

KINNOUL, dated 12th of July and 1st of August, 1764, and 9th of April and 3d of May, 1765, being read, upon consideration thereof, and of the sums subscribed in free gift towards building the bridge, it is the opinion of this meeting:

1st. That the work shall be begun next year, by raising an experimental pier, under the direction of Mr. SMEATON, as proposed by him, and that the materials necessary for raising such a pier be prepared in due time.

2d. That Mr. JOHN ADAM, architect, is a proper person to be employed in preparing such materials.

3d. That Mr. ADAM be desired and authorised to open, and try, proper and convenient quarries for that purpose.

4th. That a committee be appointed to confer and treat with Mr. ADAM, and to receive proposals from him concerning such materials, which proposals he is desired to lay before the Committee.

5th. That the said Committee shall, from time to time, as they shall think proper, report their proceedings to a meeting of the trustees, and that the clerk shall call a meeting for that purpose, whenever the said committee, or any two of them, shall desire it.

6th. That the Earl of KINNOUL; Lord GRAY; Mr. CRAWFORD, of Errol; Mr. GREENE, of Balgovan; Sheriff SWINTON; Mr. BELCHES; Provost SIMPSON; Mr. OLIPHANT, of Rossie; Mr. CRAIGE, of Dumbarney; Messrs. ROBERTSON, elder and younger, of Tullibeltan; Mr. RICHARDSON; Mr. MERCER; Mr. WOOD, Dean of Guild SANDEMAN; Baillie FYFE; Mr. WILLIAM SANDEMAN; Baillie RAMSAY; Baillie MARSHALL; Baillie FAICKNEY; Mr. THOMAS ANDERSON, and other Trustees that shall please to attend, shall be of the said Committee; and that five shall be a quorum; and that Mr. MERCER shall be convener.

7th. That the clerk shall transmit extracts of the foregoing resolutions to Mr. SMEATON and Mr. ADAM. Extracted from off the record of the minutes of the said Trustees, by

PAT. MILLER, Clerk.

EXTRACT

Minutes of the Commissioners for the Bridge over the Tay, at Perth, in relation to Mr. JOHN GWIN trying the Foundation, &c. and his Report, 1766.

AT Perth, the 27th day of February, one thousand seven hundred and sixty-six years, sederunt, the Earl of KINNOUL, Provost SIMPSON, Mr. MERCER, Mr. WOOD, Baillie MARSHALL, Mr. WILLIAM SANDEMAN, Mr. DUNCAN, Mr. ALEXANDER FAICKNEY, Mr. THOMAS ANDERSON, and Mr. SAMUEL SAMPSON, commissioners appointed by Act of Parliament for building a bridge over the river Tay, at Perth.

The Earl of KINNOUL chosen præses.

The committee appointed by the commissioners the 26th day of September last, gave in the following report of their proceedings, to wit,

At Perth, the 20th day of February, faiery ditto, and sixty years, at a meeting of the committee of the commissioners for the bridge over the Tay, at Perth, sederunt, the Earl of KINNOUL, Provost SIMPSON, Mr. MERCER, Mr. WOOD, Mr. JAMES DUNCAN, Mr. THOMAS MARSHALL, Mr. ALEXANDER FAICKNEY, Mr. THOMAS ANDERSON; the Earl of KINNOUL, Præses.

The committee having communed with Mr. GWIN, the person recommended and sent by Mr. SMEATON, direct him to continue boring at that place, which Mr. SMEATON pointed out to be the properest place for the bridge, according to the opinion he had formed when he surveyed the river, until he has discovered, as well as he is able, the metals that are to be found in the bed of the river, the whole way across the same, and that he would likewise bore across the river opposite the town-house, and in any other part he shall think proper to try; and that he will report to the commissioners, at their meeting the 27th instant, what place he in his judgment, upon full consideration of all circumstances, and upon the best information he can get of the state of the river at the different parts in the time of speat, thinks the most eligible for erecting the bridge, with his reasons for such opinion; and that he will also report the particular state of the metals as he shall find them at the different places by his boring, and that he shall likewise include in the said report a particular of the materials he shall think necessary in his branch of business for erecting the experimental pier this summer, always understanding that Mr. SMEATON is willing that such pier be erected in the most difficult part of the river, and also what number of hands it will be necessary for him to employ in this branch, in order to prepare every thing for erecting such pier as early this spring as the state of the river will admit; and Mr. SMEATON's other engagements will allow him to come here for that purpose, distinguishing what men he thinks it absolutely necessary to bring with him, and the terms upon which such men may be engaged, and what number of hands he would have engaged here; and lastly, that Mr. GWIN will acquaint the commissioners at what time he proposes to return, to begin these preparations.

The committee order the clerk to communicate to Mr. GWIN Mr. SMEATON's plan, estimate, and report anent the bridge, with his letters to the Earl of KINNOUL, and also to the clerk there anent.

The committee empower Mr. MILLER, their treasurer, to defray the expense of quarrying the stones, and to pay Mr. GWIN such sums as shall be necessary for preparing the works which he is engaged in, and for providing materials.

The committee direct the treasurer to draw upon Mr. ANDREW DRUMMOND for such sums as he shall inform him, from time to time, are in his hands, and to remit the same to the bank at Edinburgh, with the profits of the exchange.

The committee direct the treasurer to remit to the bank such sums as shall come into his hands, in the most proper manner.

The committee appoint that these their proceedings to be reported to the next meeting of the commissioners.

(Signed) KINNOUL, P.

The clerk produced a copy of a letter from Mr. SMEATON to the Earl of KINNOUL, dated the 8th instant, and also two letters from Mr. SMEATON addressed to the clerk, dated the 6th and 10th instant, all of which were read.

Mr. GWIN gave into the meeting his report, of which the tenour follows.

THE REPORT

Of JOHN GWIN, in Answer to Orders by him received, and appointed to his Inspection and Consideration at a Meeting of the Commissioners for Building a Bridge over the River Tay. February 27, 1766.

1st. Upon sounding with what instruments was practicable to get down to prove the stratum of matter in sundry places across the river Tay, from North Inch to the

opposite shore in JAMES BISSET's garden, as well as the state of the river and metals would permit, find the stratum of matter in the different soundings are as follow; that on sounding and boring in sundry places both above and below JAMES BISSET's garden, to the extent of about 150 feet in length up and down stream, found a rock close in shore upon an average lying upon 2 feet 9 inches below the top surface of the gravel, and extending itself from the shore towards North Inch, as near as I could judge, about 300 feet, before I could exactly say I thought it left, and continued to be very level, not varying 1 foot in depth in the above length. This top crust, or supposed stratum of rock or hard cemented gravel, consists equally alike in all different places of trial by boring, and appears to be a shaly hard consistence for about 8 inches thick; but upon further speculation, to prove its consistency of metal, found that we could force a sharp-pointed iron bar down 6 feet deep (in some parts 8 feet deep) into the said stratum of shaly matter, always observing the bar went moderately easy after it got through the upper crust before mentioned, and did not begin to fasten till at about 8 feet or 9 feet in general, and then it came to a matter much more firm and solid. From this place, which is not quite the half over to the North Inch, the stratum grows somewhat softer after we got down 7 feet from the top surface, which seems to run, on a medium, nearly on a level, it being a stratum of sound firm gravel, and then, for about 2 feet 9 inches, it appears to be a sandy gravel (by what our rods brought up), and under that, at about 10½ feet from the top surface, on an average, we come to a firm sound gravel as before.

Upon boring on the shore in JAMES BISSET's garden, in two places, at the distance of 30 feet from the water's side, find the stratum of matter to be from the top surface to 6 feet deep a blue corn mould earth, and from that down 5½ feet a quite shear sand intermixed with a little gravel, which both together makes 11 feet 6 inches, at which depth we came at the rock, which lies nearly level, and rising in its bed but very little up the hill. On the North Inch side on land we bored, we find corn mold earth to the depth of 5 feet from the surface, and from that to the depth of 3 feet a sharp shear sand, then came to a loose gravel for about 2 feet, after which it continues loosish to about the depth of 8 feet, at which depth it appears to be a quite solid gravel, and is all the particular situations of the stratum of matter consisting in the bed of the river, across from shore to shore, at the above mentioned place, to the best of my opinion.

2d. Upon sounding the aforesaid river from the town-house to the opposite shore called Bridge End, find the metals in the bed of the river as follows. Having drove a sharp pointed iron bar in sundry places up and down stream for near 120 feet in length, but could find no place to get the bar down from the upper surface about 4 feet before it met with some of the ruins of the old bridge, which lay spread up and down in that channel for about 60 yards facing the High Street, and extending about 80 or 100 feet breadthways across the river; after which, on sounding from thence to about 80 feet of the opposite shore in sundry different places, found the stratum of matter so soft, as to admit a bar being forced easily down into it 12, 14, and 16 feet, and even at that depth no solid matter appeared. The soil, from what I can judge, is a sandy clay, at about 6 or 7 feet from the top surface, which is all the particular description of the strata of matter in the above situation, to the best of my opinion.

3d. Regarding which of the two before-mentioned places is properest to erect the bridge, my opinion is, that the suitablest place for the bridge to be built near the town of Perth, is from the North Inch to the opposite shore, in JAMES BISSET's garden, (for reason 1st.) The river is more extensive in breadth than in any other place

adjacent to the town. (2dly.) In extreme floods the water having liberty to extend itself to a great surface, and by the intended situation of the bridge being at a proper distance from the mill lead, consequently will give room and scope for a great quantity of water to issue in there on the down-stream side of the bridge, which will cause a lethe of water to constantly be recoiling back to the bridge, and meet the currency, and thereby ease in a great measure the pressure and weight on the bridge, (3dly.) Its situation in this place is much more desirable, as it is across a ford, which by the best accounts I can learn has not been known to shift these many years. (And lastly.) It has been remarked, that during the late storms, wherein the Tay has discharged great quantities of ice, which has floated up and down with the tide, it was not known that scarcely any ice went up above the said ford, but has been known to gorge up the river in different places to an almost incredible height below the said ford, particularly at or nearly opposite the town-house, which would be a very great obstruction to the water-way in a flood time, provided the bridge was pitched upon to be built across this part of the river; besides, another reason in my opinion against this situation not being suitable is, that the river is more contracted from shore to shore, it being but 567 feet across from the town-house wharf to THOMAS TYFF's house, besides its bounds are shorter than that, as much as it is across from the wharf side to his house, which is 34 feet, which reduces the water-way so much less; and (3dly,) on continuing the proper length of the bridge, find that, according to plan, the bridge foot will terminate above 50 feet above Waller Gate Street, which will render the low rooms of the dwellings contiguous thereto invalid, by the bridge being so high above them on both sides, supposing all other circumstances agreed with its situation.

4th. Regarding the part of the river in which the first pier should be fixed, am of opinion, that one of the centre arch piers will be as difficult as any, for reason, if we are to go down to that lower bed or stratum of hard gravel, it will be a difficult matter to drain it, for the getting out the excavation and foundation laying, or the third pier nearest the bridge end shore, it being the deepest water there.

5th. Regarding the quantity and quality of sundry materials in timber necessary for the erection of one pier, in making a coffer-dam and pumps and engines, and all other materials, &c. such as tackles and shear-poles for the masonry, and hand and wheel barrows for the excavation, and likewise, in case the pier should be ordered by Mr. SMEATON to be piled in the foundation, the stuff wanted will be as followeth: for the coffer-dam and other uses 2274 cube feet of oak and elm, and 150 cube feet of Riga timber, about 200 superficial feet of ash plank for barrows, about 15 Assar baulks, 20 feet long, for stages, and tackle poles, &c. about 30 Dantzick 3 and 4 inch planks, 20 feet long, for stages and runs for the barrows in the excavation, likewise about 30 inch and half Dantzick planks for engines, and pumps, &c. about 14 or 16 feet long: and lastly, if it comes to be a timber foundation (not that I pretend to know in what manner Mr. SMEATON will pitch on it to be done), but only in case it should so happen that he thinks it necessary; in such a case, I have made a rough calculation what stuff we should have in readiness against such thought as may to him seem best, which appears it cannot be less than 1000 cube feet of oak and elm, though I think it would be full enough, only it would be proper to have some to turn our hands on.

Regarding what number of my workmen I think necessary to bring with me from England, I intend to bring two men and my apprentice. As to terms, Gentlemen, as they will be employed in your service about five months, or nearly so, and then have to go home back again, I think I cannot engage them otherwise than at 14*s*.

per week each man, and the apprentice to be 7*s.* with their time and moderate expenses on the road going and coming paid them.

7th. Regarding the quantity of other workmen necessary in my branch for carrying on the pier, to be assisting with my men, I think four carpenters and ten labourers will be sufficient for the expediting the work; but the latter will not be wanted till we begin to take off the water.

With the blessing of God, if I continue in good health, I propose to be at Perth in six weeks time, from the setting off on my journey to my coming again, provided all materials, or part to begin, be got to a proper place to work, upon notice, which I presume will be sent; and I think, if agreeable to you, Gentlemen, that Mr. SANDEMAN's saw-mill will be the properest place to work up the materials, as the stuff may be sawed by the mill and worked up there, and then sent down to the work by water as wanted, and not be liable to be any of it lost by floods.

Signed, JOHN GWIN.

Which report being read, the Commissioners direct Mr. GWIN that he will immediatly, upon his return to England, communicate the said report to Mr. SMEATON, and desire Mr. SMEATON to ascertain the materials which he shall think most proper and necessary for the timber work that is to be prepared for erecting the experimental pier; and that he would, as soon as possible, transmit to Mr. PATRICK MILLER an account of the materials so ascertained by him.

The Commissioners approve of Mr. GWIN's terms upon which he proposes to bring down from England the two workmen and his apprentice.

The Commissioners recommend it to Mr. GWIN to regulate his return so that the necessary preparations may be ready at the time it will suit Mr. SMEATON's convenience to be here; and they direct their clerk to deliver to Mr. GWIN a copy of their minutes in so far as relates to his report.

Extracted from the records of the said Commissioners by me

PAT. MILLER, Clerk.

DESCRIPTION AND METHOD

Of fixing the Foundation of the Second Pier of Perth Bridge, according to the Plan.

METHOD OF FIXING THE COFFER-DAM.

The gravel turning out harder than was expected in the last pier, and it taking up much time in driving the piles of the coffer-dam down to their proper depth, and also finding them very difficult to draw, and much shattered when drawn, I propose for this pier that as many additional piles be procured as will set the whole at the distance of 9 feet from sheeting of the base of the pier, and to drive them no further than to fix them firm in the ground, which if that happens at 2 feet will be sufficient. The dam being then completed to its proper height, in order to guard against filtration of the water under the bottom of the piles, I propose to throw in all round on the outside a quantity of gravel and corn mold earth mixed together, so as to lay rather sloping against the piles, and extending about 6 feet all round: the gravel being mixed with the earth, will not only augment its quantity, but prevent its being

carried away by the stream, the use of the earth being to choke up the chinks and pores of the gravel upon the bed of the river. I apprehend about a cube yard of compound matter, to a yard running, thrown in, will be sufficient, observing to begin the work at the salient angle up stream, and proceeding gradually downwards on both sides, closing at the salient angle down stream.

METHOD OF MAKING THE EXCAVATION.

The pumps being fixed, and the water pumped out, begin the excavation no larger than the base of the pier, and having got down a space in the middle to its proper depth, increase it in width and length till the area is clear for driving the piles upon which the foundation frame is intended to rest, and no more, leaving the matter on the outside of that area to form its own slope towards the coffer-dam, so that the rest of the area will be left solid, to support the sheeting of the dam; and if any part seems feeble, or likely to give way, let it be strengthened by driving piles for supporting slate on edge, as the nature of the ground and circumstances shall shew to be necessary, observing, in beginning the excavation, that the matter be thrown out all round, so as to secure and strengthen the matter first thrown on the outside of the dam.

The depth of the excavation will be found by the following rule. It must at least be excavated 3 feet at a medium below the natural surface of the gravel where the pier stands; but if this does not carry down the base of this pier within 2 feet of the level, at which the base of the first pier was fixed, let the depth of the excavation be increased till it is within 2 feet of the former depth.

METHOD OF FIXING THE FOUNDATION ACCORDING TO THE PLAN.

The excavation being made, as far as is above directed, let the 21 piles, upon which the frame rests, be driven into their proper places: these piles are to be 10 inches heads, and of 6 feet long, supposing the gravel of equal strength with the last, but if there is any reason to suppose it stronger or weaker, the length above mentioned should be increased or diminished. This being done, and the pile heads reduced to a level, lay down the frame thereupon, which I suppose to be ready prepared in the yard, with the tye beams ready fitted with dovetails thereto, and being trenailed down upon the respective pile heads, proceed to drive the sheeting piles, which may be of oak, elm, beech, or fir, as can best be got. I suppose them to be of 6 feet long; they may be driven plain, as shewn on one side, as was done at Coldstream Bridge, but would be preferable if rebated, as shewn on the other half. The choice of the method depends on circumstances; if, from experience of the other pier, they are like to drive regular, without tearing of the rebates, by meeting with great stones, &c., then they will both drive more regular, and hold firmest by being rebated, but if they are apt to split, then it will be as well to save that time and labour, by making them plain, and more especially so if the difference of expense in workmanship, or hindrance of time in doing it, is likely to be a material object, in that case the rebating may be omitted.

N.B. If driven plain, the breadths of the piles are not material; but if rebated, narrow piles will enhance the workmanship in preparing. In order to save timber (and especially if fir piles are made use of, it will be much stronger) I propose to groove the piles on both sides, and to nail in the tongue, which, if fir piles, may be of harder wood; the best proportion for fir piles would be to make the tongue $1\frac{1}{4}$

inch thick, and $1\frac{3}{4}$ broad, to be let $\frac{3}{4}$ into the side where it fastens, and to stand out 1 inch; but this may be done according as the tools already prepared may suit, there being no need to make new ones on purpose.

The tops of the sheeting piles being reduced to a level with the string pieces (and spiked thereto as they are driven) the outside must be reduced to a regular breadth, so as to take the notched stones in a line. This being done, the rest of the bearing piles must be driven, beginning with the outside rows, and cut to a level with the top of the string pieces; these piles may be of 6 feet, more or less, according as the others are found to go.

The setting must be completed by first underpinning the string pieces and tye beams as firmly and equally as they can, by moderately driving stones under them; and lastly, the other spaces to be set, and well drove down as before; but before they are rammed down, the joints of the setting should be filled by sweeping in dry lime mixed with sand and small gravel, that when drove down the whole may be compact together.

When the pier is got above low water, I would have the matter taken out for 4 feet wide round the pier, down to the level of the top of the notch course, and filled with good lagging as before, standing somewhat higher than the natural bed of the river, and the rest of the space covered with rubble to the sides of the dam.

N.B. I suppose the bearing piles to be sufficiently drove, when it takes 20 blows of a sufficient ram to drive an inch, and the sheeting piling to be so when it takes 40 blows to drive the same quantity; but the sheeting piles should be drove as near to a regular depth as possible.

Austhorpe, April 23, 1767. J. SMEATON.

P.S. I do not mean to set aside the use of such materials as were prepared according to the plan of last year, unless utterly inconsistent with the present.

PERTH BRIDGE.

Perth, October 5, 1787.

Having this day viewed the bridge of Perth, I have the satisfaction to observe every thing relative to it in perfect good condition, the walking path over it excepted; which, from the want of hardness in the stone wherewith it has been laid, is not only much worn, but, from the hard pebbles imbodied in the stone itself, is become very rough and uneven. For the effectual restoration of this part, nothing would be so completely durable as to remove the present stone-work, and relay the same with Aberdeen granite of the same depth as the present. But as the present stone-work of the walking path appears to me to lie completely firm and solid, and being shewn a sample of the Kingudie flat paving, which I understand can be procured of any thickness, with parallel surfaces, and also appearing to me to be of a nature sufficiently durable, I apprehend the work may be executed in a substantial manner, as follows:

The stone from Kingudie being procured of 4, 5, or 6 inches' thickness, as can be most conveniently had, and of such lengths as to make good the whole breadth of

the walking path without a joint, but of promiscuous breadths in the direction of the bridge, I would advise to chissel or broach off the upper surface of the present walking path till it comes to a regular height, and then with good mortar to lay down the Kingudie flooring, close jointed, upon it, making the joints of the flooring with the best Pozzelana mortar; and in case there is Pozzelana remaining in plenty, it would be well to give the mortar wherewith the flooring is bedded an allowance of Pozzelana, as, suppose, half the quantity; observing to level the surface of the present mass of stone in such manner as to allow a drip or declivity from the parapet towards the carriage way of about $\frac{3}{4}$ of an inch; and also to make the breadth of the new flooring about $\frac{3}{4}$ of an inch short of the present breadth, so that the tread of the carriages being taken off from rubbing against the Kingunie flooring, it may remain undisturbed being defended by the solid of the present; and in the same way the walking path may be set with Aberdeen granite, provided it is worked to a parallel thickness.

With respect to the paving of the bridge, there is no objection to it as to the structure, this being merely a matter of convenience, of which those who from their local situations observe and use it can be the best judges. I have only to observe that the Aberdeen granite paving is not only the most durable of any that I am acquainted with; but, from its roughness, the horses' feet are the most steady, and hold the firmest in drawing upon it. The blue whin is the next in degree; so that where the blue whin is procured upon the place, I cannot think it necessary to send for the Aberdeen granite from a distance.

Having viewed the bulwarks that have been erected opposite the Inch upon the north-east side of the river, I am of opinion that all such works as cross and intersect the stream of the river, or interrupt the water from gliding freely away, are the means of increasing the stress upon other parts, and, therefore, as affecting other properties, should be avoided. When properties want a defence against the incroachments of the waters, it should be by disposing those defences at the foot of the banks, in a direction parallel to the stream, and without interrupting its free course.

J. SMEATON.

CHRISTCHURCH HARBOUR.

The Report of JOHN SMEATON, *Engineer, upon the harbour of Christchurch in Hampshire, from a view thereof taken the 20th and 21st of May,* 1762.

THE harbour of Christchurch is situated in the bottom of a deep bay, formed between the isles of Wight and Purbeck, and at the mouth of the two large united rivers, Avon and Stour; the passage of which to sea is between two natural points of land not much above 50 yards asunder at low water, within which points the river forms a large inland bay or bason, which is properly the harbour or haven of Christchurch, and is defended from all winds: with those outlines one would be naturally led to expect a good harbour, capable of receiving a number of large ships; yet, notwithstanding these great advantages, nature has ordered it otherwise.

About a mile or better to the S.W. of the harbour's mouth begins a high point of land, called Christchurch Head or Heads, for the coast, in running further to the

S.W. forms another, which makes a double head, with a small recess or bay between; these heads, as well as a considerable part of the coast extending westward therefrom, stand bold upon the sea, the foot thereof being washed by its waves at high water. Those heads have formerly extended much further into the sea than at present; but being composed of a loose sand, intermixed with some quantity of loose iron-stones, the action of the sea upon the foot of these cliffs in time of storms brings it down in great quantities, and is driven by the violence of the seas with wind from S. to S.W. into the bottom of the bay, and there being subject to no counteraction by the opposite winds, it has not only greatly obstructed the bottom of the bay with sand, but has spread itself to a considerable distance from the shore. It further seems to me that the harbour's mouth has formerly been much more extensive than at present, having reached even to the heads; but the sand gradually coming down from the cliffs, and being driven into the haven by the S.W. and S.E. winds, has gradually formed marshes to the N.E. of the high lands, and thereby drove the mouth or channel of the river gradually to the N.E., and again, by the blowing of the sand, left dry at low water, by the S.E. wind, it has formed a range of hommacks or sand-hills, extending from the heads north-eastward to the south point that now forms the harbour's mouth, and has thereby formed a natural bank, part of which separates the bason, now composing the harbour of Christchurch, from the sea. The sands thus moving seem to have forced the mouth of the river as much to the N.E. as it well can be; and undoubtedly the whole had been long ago shut up, had it not been for the powerful reaction of the fresh waters continually pressing toward the sea from the two rivers aforesaid, which, in wet seasons, as they drain a vast track of country, must be very considerable; and, indeed, by the power of such a collection of fresh waters, great things might be done, did not nature throw out another rub in the way—and that is the small flow of the tides at this place.

The great depth of this bay from the main channel tide, the shoalness of the waters occasioned by the sands before mentioned, and the distraction of the current in going different ways round the Isle of Wight, I look upon to be the most probable cause of the smallness and irregularity of the tides here. It is not reckoned that the spring-tides rise more than from 5 to 7 feet, and the neap-tides from 4 to 6; so that it sometimes happens that the neap-tides are higher than the springs, depending much upon the course of the winds; the tides are said to be highest with a S.E. wind, and least with wind at N.

I am also informed, that, three hours after the regular time of high water, when the main tide in the channel begins to set towards the west, a second tide is formed in this bay, which is generally highest at neap-tides, and that the ebb between the two tides is from 8 or 9 inches to 18; which second tide, proving a check of the reflowing power of the land waters, tends to weaken their force in getting to sea.

From the circumstances before described, viz. the flatness of the bottom, the constant motion and increase of the sands, and smallness of the tides, I cannot flatter the inhabitants ever to expect a harbour at Christchurch of any great depth or capacity; yet, at the same time, it seems to me capable of great improvement, as will appear from a further description.

Between the points I found a considerable depth of water, but as the width of the channel greatly enlarges without the points, the depth diminishes, and at the distance of about 200 yards a hard gravel shoal is formed, and, still further out, the bar. From the points to the bar the channel lies E. by S. and from the S. point there runs out a sand, which is dry at low water, and extends from the said point on the S. side of the channel, and in a parallel direction thereto, as far as the bar. This

view was taken on the second and third days before the change of the moon, so that the spring-tides were scarcely set in.

At this time I found 16 feet water between the points, 4 feet 9 inches upon the gravel shoal, and 5½ water upon the bar, and in the road, which lies about half a mile further out in the same direction, 16 feet water; the bottom is said to be a strong blue clay; the Needles bearing S.E. by S. and Christchurch Heads S.W. and just open one with the other. Within the points the channel turns S.W. by the side of the hommacks before mentioned, and from 16 feet, as it is between the points, comes to 7, 6, and 5 feet.

Christchurch Quay lies about two miles up the river from the harbour's mouth, between which there are the following shoals, beginning at the harbour, viz.

Friscum Shoal, water thereon 4 feet 9 inches (when 5½ at the bar, as above); a loose gravel or shingle 2 feet deep, then turns harder. Ganbury Shoal, 5 feet water; bottom, soft mud and sand. Saltmard Corner, 5½ water; bottom, loose gravel or shingle. The Pick had 6 feet 3 inches water, and a loose gravel or shingle bottom. There was no other place in the river but what sounded 6 feet or upwards at the said tide.

About 1 furlong from the S. point of the harbour's mouth, towards the S.W. is run out a kind of jetty or pier in a straight line, composed of round lumps of iron-stone, which have been brought from the heads; its direction is S.E. and extends from high-water mark 256 yards; the Needles bear from thence S.E. by S. so that it is land-locked thereby a point of the compass; its top gradually declines from the shore towards the sea, the whole being uncovered at low water, but all or the greatest part covered at high water. Round the end of this pier I found about 7½ feet water, and at about double this distance from the shore about 10 feet (when 5½ upon the bar), the water being rather better to the N.E. than to the S.W. of this line, the whole bottom being sand, and almost regularly inclining from the shore in the proportion above mentioned.

From information, I learn that the aforesaid pier or jetty was erected in the reign of King Charles the Second, and intended for securing a better passage into the harbour, and that for this purpose a cut was made through the hommacks, so as to let the water through the same out of the harbour, and so as to direct its course to the S.W. side of the pier.

This pier, it seems, was intended for the N.E. pier; another pier being designed on the S.W. side of the channel; the other passage in or near the present place was then stopped up with piles, &c. at a considerable expense: this course was maintained for some time, and a deep channel was made by the back waters alongside the pier of 15 or 16 feet deep; but then the matter being deposited, and the force of the land water being spent as soon as it quitted the end of the pier, there still must remain there a bar of the same height as the present bottom; however, as that bottom is at least 2 feet lower than the present bar, it would make at least 2 feet more water into the harbour, which must, of course, prove a very great improvement so long as it lasted. But before a long time had passed, it happened that the back waters, not finding a passage to sea sufficiently ready through this new channel, broke over, and forced themselves a fresh passage at the present place, which has ever since continued, and the artificial one was presently shut up by the sea.

From a due consideration of the facts and circumstances above recited, it appears to me as follows.

1st. That from the tendency of the land waters to open and preserve themselves a passage to sea at or near their present place, and from the tendency of the sea to

shut up any passage made to the S.W. that the present course is best adapted by nature to be maintained: this is further confirmed by the bottom of the road, which, lying further out in the same direction, is clear of sand; but as the distances from the points to the bar, and from thence to a sufficient depth of water for an entry to a tolerable harbour, to which place two piers ought to be carried out to confine the land waters, and protect the channel from the driving in of the sand, in order to render the same effectual,—I say, the great length required for such piers appears to me likely to be attended with too great an expense, added to the great trouble and difficulty in moving the gravel shoal before mentioned; otherwise, in my opinion, this construction would be the least exceptionable.

2d. It appears to me that the grand mistake in the former attempt consisted in constructing the wrong pier first; or, in other words, in making the channel on the wrong side of it: otherwise, for aught that to me appears, it might have maintained itself an open passage to this day; for had the S.W, pier been built first, or what amounts to the same thing, had this been made the S.W. pier, by making the passage on the N.E. side of it, then it would not have only defended the passage from the sands brought down from the S.W. by the action of the winds and storms from that quarter, but the sea, by breaking over the top of it, would have tended to have deepened the channel on the leeward side; whereas, by making the channel on the windward side, it would tend to intercept the sands, and thereby immediately to fill up the channel, had not the superior force of the back water carried it out as fast as brought in; so that I rather marvel a passage was ever this way obtained, than that it should be filled up in the way it was managed.

That this must be the case in some measure, appears from the manner in which the sand now lies contiguous to the pier; for, notwithstanding it is within 2 or 3 feet of the top, yet it lies on the S.W. side at least a foot higher than on the N.E. Indeed, I cannot account for a conduct so absurd, otherwise than by supposing the projector imagined the sands to be immovable, with respect to the winds and seas, and not in a travelling state; and, observing the strong tendency of the channel to travel to the north-eastward, proposed to stop it by interposing the pier. From this attempt, however, though unsuccessful, we may learn how strongly the land waters acted, and what may be done by better management in the same situation.

The direction of the pier S.E. is very good, for vessels may sail in or out with a S.W. wind; it could not be pointed more southerly, so as to give advantage to vessels going in with wind nearer west than they can now do, without giving advantage to the seas from S.S.E. to roll more directly in, as it would then not land-lock with the Needles, but point to the open sea; its situation is also very good, as it stands almost direct in a right line with a reach of the river, and if a vessel should not make the entrance of the harbour, they will have the road to the leeward.

I would, therefore, advise to construct another pier parallel to the present one, but on the S.W. side thereof, and at the distance of about 240 feet from middle to middle; and when this is carried out from 50 to 100 feet further than the present pier, then to attempt to open a passage through the hommacks, so as to turn the water between them, and at the same time to divert the water from its present course at low water by a catch-dam of rough stones, or by a composition of piles, fascines, stones, &c. By these means a sufficient channel being procured between the two piers at low water, that channel will gradually deepen, and the present channel being deprived of the greatest part of the reflowing power, the sands that are now kept out

by the same will begin to close in, and, in time, will form hommacks so as make an entire stop at high water, and the progress thereof, as occasion may shew necessary, may be helped by art.

By these means the earliest advantage may be taken of the undertaking, and vessels drawing 8 feet water may be brought in at a middling spring tide; and as I would advise the whole to be performed by throwing in of stones upon the same principles as the present pier has been built, the piers may be gradually lengthened, constantly advancing the S.W. pier before the N.E. and it appears, that by extending the piers to double the length of the present, that is, to the length of about 500 feet, there will be 2½ feet more water, that is, there will then at mean spring-tide be 10½ feet water, and at neap tides 9½ feet, which will make a very good harbour for small merchant ships, coasting vessels, armed cutters, &c. And as it appears that an extension of about 250 feet procures 2½ feet water, it follows that every 100 feet extent of the piers will procure an additional foot of water, so that the improvement of this harbour may be carried on to any extent, by gradually lengthening its piers, as time, circumstances, the utility of the harbour, and ability to execute, shall suggest.

I do not think it necessary to do any thing to the present pier, till the west pier is carried out as directed, and the water let in between them; but I would advise the west pier never to be left till it has got above high water. It must at first be made considerably higher than high water, for as I would not advise attempting to dig away the sand for a foundation, whenever the current is turned against it, it will settle very considerably, and unless a good body of stone is originally laid, may settle so much as to make it difficult to add to the mass at top. It is for this reason I would not advise to make the present pier the west pier, for having had a deep channel on the west side of it, the matter thereof on that side had got sufficiently compacted to a due depth; but was the channel made on the east side, the foundation being there shallow, would be undermined, and occasion it to settle afresh, and require a large addition of materials to make it up to the same height.

As the tides are said to rise from 4 to 7 feet upon the bar, 5½ will be the mean, which was what I observed; and as I found no part of the river between the harbour and the town of Christchurch, but what, at that time, sounded 6 feet and upwards, except the shoals before specified, all which are composed of soft and loose matter, and of no great extent, I look upon it as very practicable, by dredging, to make good a 6-feet channel from the harbour to the town quay, at a mean tide, which will be very sufficient for all kinds of lighters and small craft. This may possibly be done by the river itself, whenever it gets a more sufficient outlet to sea; and much more cannot be expected, without a very considerable expense.

The iron-stones now lying upon the sands under Christchurch Heads, are a very proper material for the construction of the works above mentioned; but I fear they will not be found in sufficient quantities: if not, rough unformed stones may be brought from Peveral Point, or Portland, the cap of which is refuse, and will answer as well as finest stone.

I have added a sketch of the harbour, as it appeared to me on view, and the measures above specified, wherein what is done in red is the proposed works.

As this is a work that depends much upon circumstances, it is not easy to make a tolerable estimate; yet, to give all the satisfaction in my power, the best I can judge of it is as follows.

ESTIMATE

For the Works proposed to be constructed at the Harbour's Mouth, according to the preceding Scheme.

	£.	s.	d.
I suppose the great S.W. pier will, at a medium, take 224 cube feet of matter in each foot running, and for 1500 feet, 336,000 feet; this, allowing 12 feet of iron-stone to the ton, will produce 28,000 tons; and supposing this to be brought from the heads, and laid in place at 2*s.* per ton, will come to	2800	0	0
For the prolongation of the north-eastern pier 210 yards, I suppose 168 cube feet per foot running may be sufficient, and this, for 630 feet, is 105,840 cube feet, which will make 8820 tons, at 2*s.*	882	0	0
For making a cut through the hommacks, at a medium, 66 yards long, 66 yards wide, and 3 yards deep, will contain 13,068 cube yards, which at 4*d.* comes to 217*l.* 16*s.*; but as some work will be required in clearing away some of the sand between the piers, till a passage can be procured, if for this service we reckon 82*l.* 4*s.*, the whole will be	300	0	0
For covering the border of the new cut with stones, so as to prevent its washing, and thereby to prevent the water from getting part behind the piers; this, at a medium, being faced up half a yard thick, will take about 1500 tons, at 2*s.*	150	0	0
For making a catch-dam to force the water of the haven through the new cut and between the piers, at low water; this, if constructed wholly with rubble, and being supposed, at a medium, to contain 70 feet cube per foot running, this, for 720 feet in length, will require 4200 tons, at 2*s.*	420	0	0
To incidental expenses, at 10 per cent	455	0	0
	5007	0	0

N.B. As the quantities are given, if the iron-stone can be moved cheaper than above set down, the saving will be in proportion; but if the quantity above specified cannot be got from the heads, what will be necessary to be brought from Purbeck or Portland will be at an advanced price, and will, at least, I suppose, come to 5*s.* per ton; but it is to be noted, that one ton of this stone makes 16 feet.

Austhorpe, August 13, 1764. J. SMEATON

ADLING FLEET LEVEL.

The Report of JOHN SMEATON, *Engineer, upon a View and Observation taken of the Level of Adling Fleet, &c., from a Plan of the said Level, taken by Mr.* CHARLES TATE, *Surveyor, in the year* 1764.

IN the year 1755, I was employed by the owners of the manor of Haldenby to take a general view of this level, in order to form a scheme for the drainage thereof; and finding that the great defect lay in the drains and out-fall clough, I made a report, shewing how these defects were to be remedied, to the general advantage of the whole, as well as Haldenby in particular, as will more fully appear by reference to the said report, not supposing at that time that the proprietors would be willing to be at the charge of getting an Act of Parliament, in order to enable them to make new drains in any more proper direction.

The present view and report being made at the general request of the principal proprietors of the said level, who not scrupling the expense of an Act of Parliament, in case it should be requisite, I have taken a further and more minute, as well as unconfined view of the whole; and though from hence it appears that a more eligible course of drainage offers itself than the old one formerly proposed, yet it also appears, that had my former directions been put in effectual execution, the proprietors would have found no occasion for a second application, and would have reaped the benefit of the improvements during the intermediate time. I also find the coin

cidence of the levels taken then, and now, surprisingly great, considering the badness of the season then, and that the greatest part of the low grounds were then under water, there being but 2 inches difference between the fall from the lower part of Haldenby Common (which is the lowest land) and the floor of our fleet clough, as taken then and now, as will appear by comparison of the former observations with the present; but as the latter observations were made under more favourable circumstances, and with more accurate instruments, I shall chiefly rely upon my last observations, which are as follow.

	Ft.	In.
Rise from low-water mark at the Ouse, September 1764, to the floor of Hackensyke or Ouse-fleet Clough	3	0½
Rise from the floor of the Clough to the surface of the water in the drain at Coat's Bridge	4	9
Rise of water from low-water mark at the Ouse to Coat's Bridge	7	9½

Many parts of the bottom of Hackensyke Drain are not more than 14 inches below the level of the surface of the water at Coat's Bridge.

Rise from low water at Trent Fall to the surface of the water in the drain at Coat's Bridge	9	5
Fall of the Ouse from Hackensyke Clough to Trent Fall	1	7½
N.B. The rise of the different points of the land above the water at Coat's Bridge, is inserted in circles upon the map.		
From Coat's Bridge, for the run of the water through the drains, I allow to the stagnant water on Haldenby Common a rise of	0	2
N.B. The depth of this stagnant water was in general about 9 inches; from this stagnant water to Green Bank, the water along Eastoft Drain was in general stagnant; but the sum of the rise taken at different stoppages amounted to	0	8
Rise from thence to the mean surface of the land near the head of the division drain, between Eastoft and Whitgift, on the north side of Green Bank	0	7
Rise from Coat's Bridge water to the general surface of the land on the north side of Green Bank	1	0
Rise from the general surface of the lands on the north to the surface of the water in Eastoft Drain, south of Green Bank, which were upon a level with the lowest lands there	1	2½
Rise from Coat's Bridge to the surface of the lowest lands in Eastoft, south of Green Bank	2	2½

CONSEQUENTLY,	Ouse at Hackensyke Clough. Ft.	In.	Trent Fall. Ft.	In.
The lowest lands in Haldenby above low-water mark at	7	2½	8	10
The lowest lands in Eastoft and Whitgift Moors, north of and contiguous to Green Bank	8	9½	10	5
The lowest lands in Eastoft, south of Green Bank	10	0	11	7½

As I found no considerable quantity of water remaining upon the tract of country under consideration, except upon Haldenby Common and adjacent places, it follows from hence that, agreeable to my former observations, Haldenby Common is the lowest part thereof, and consequently what will drain this part will, of course, drain all the rest; and since this part lies 4 feet 2 inches above the floor of Hackensyke Clough, it may be wondered why 9 inches water should remain thereon in a dry season; but as it also appears that many parts of the bottom of Hackensyke Drain lie but 14 inches below the water of Coat's Bridge, it will of consequence be not more than 7 inches below the land surface of Haldenby Common; from which if we take 3 inches for the declivity of the water, to produce a sensible run to the place of obstruction, there will remain only 4 inches for the depth of water upon the bottom of the drain, which is so small a body that the water cannot be run off in the course of the summer, if it should prove showery; nor otherwise, till it is evaporated by the

sun and winds, which are the only means by which this piece of ground can be drained, as things are now constituted, I thought proper more particularly to remark this fact, because it at once points out the cause and cure of the evils that attend the whole level.

That Haldenby Common admits of drainage by Hackensyke Clough, even as it now stands, appears hence.

	Ft.	In.	Ft.	In.
The whole fall from the surface thereof to the Clough floor, being			4	2
Suppose 6 inches thickness of water to go over the first floor	0	6		
The surface of the water being reduced 2 feet within soil, makes a complete drainage	2	0		
Sum			2	6
Remains the declivity of the water's surface in the drains between Haldenby Common and the Clough			1	8

The distance by the course of the drains, straightened according to A B G H I e f, will be 3 miles 2½ furlongs nearly, which is full 6 inches per mile, which is within the limits of a good drainage.

Hence it appears, beyond a doubt, that the whole level may be drained by Hackensyke Clough, as it now stands, provided drains of proper depth and capacity were made correspondent thereto; but as that Clough lies full 3 feet higher than low water mark, it is capable of being laid so much lower, and the drains being proportionably deepened correspondent to this lower situation: this would occasion so considerable a descent, as to run off the waters of the greatest downfals as fast as they came down, without danger of overflowing any of the lower grounds, which might sometimes be the case, was the Clough continued at its present height.* Let us now see what fall will be obtained, upon a supposition that the Clough floor was lowered 3 feet.

	Ft.	In.	Ft.	In.
The whole fall from the south end of the moors contiguous to Green Bank, to the present Clough floor, is			5	9
And the Clough floor being lowered 3 feet, would make			8	9
The distance by the course of the drains straightened, according to the letters A B C D E F h, will be not quite, but near upon five miles, and supposing we allow a descent of 1 foot per mile, which is very ample and sufficient for any purposes of drainage, the whole descent would be	5	0		
And allowing for the thickness of water going over the floor	0	6		
Sum to taken from the whole fall			5	6
Remains the quantity that the water will be reduced within soil, at the most remote low places			3	3

N.B. This is 1 foot 3 inches more than necessary, and will be more at all nearer distances, as further appears, thus:

	Ft.	In.	Ft.	In.
The fall from Haldenby Common to the Clough floor, if laid 3 feet lower, will be			7	2
The descent for 3 miles 2½ furlongs, at 1 foot per mile, will be	3	3¾		
The water over the floor	0	6		
The sum deduct from the whole			3	9¾
And there remains for the reduction of the water within soil at Haldenby Common			3	4½

Hence it appears, that was Hackensyke Clough floor laid lower by 3 feet, and the drains properly adapted thereto, that it would be as effectual as could be desired.

* N.B. This would be prevented by gates being erected, as mentioned in my former Report.

It next comes in place to inquire, whether new drains in a different direction, and to a different out-fall, may not be more eligible than the former; and from inspection of the country it appears, that the natural course of drainage tends from Haldenby Common towards Trent Fall, which is undoubtedly the lowest ground; and it also appears from the levels, that there is a greater fall thither than to the Ouse at Hackensyke, by 1 foot 7½ inches; it also appears by the plan, that the distance, according to the course of the new proposed drain *a b c d e f g h*, is rather more than 5¼ miles, which is somewhat more than ¼ of a mile more than the former, which in this case is inconsiderable: if, therefore, the drainage to Hackensyke Clough is as complete as can be required, when laid 3 feet lower than at present, it will be still more unexceptionable when laid at the same depth at Trent Fall; for, as it will then lie 1 foot 8 inches above low water mark, it will run a greater length of time at each tide, and, therefore, the drains, after making proper allowance for the difference of distance, may be of less width than would be required at Hackensyke to be of equal effect.

The falls will then stand as follows:

	Ft.	In.	Ft.	In.
From the surface of the moors north of Green Bank, to the floor of the sluice at Trent Fall, laid 3 feet below that now at Hackensyke			8	9
Thickness of water over the floor	0	6		
Fall of the water 5¼ miles, at 1 foot per mile	5	3		
The sum to be deducted from the whole			5	9
Leaves for the reduction of the water within soil at Green Bank			3	0
Again. From the surface of the land of Haldenby Common to the floor of the sluice at Trent Fall			7	2
Thickness of water over the floor	0	6		
Fall of the water according the course *a b c d e f g*, 3½ miles, at 1 foot per mile	3	6		
The sum to be deducted from the whole			4	0
Remains the reduction of water within soil at the lowest part of Haldenby Common			3	2

This reduction would drain even Plumb Groves and Robinson Deeps, was it not advisable to reserve those undrained for watering cattle; for which purpose it will also be necessary to have land-doors to the out-fall clough or sluice, to pen the water at dry seasons, and also at some other places: but as those will be private works it will be needless to insist thereupon. The proper widths, depths, and dimensions of the drains and sluice are contained in the following estimate. The course relative to Trent Fall are coloured yellow; those to Hackensyke, red.

This level is very well circumstanced with respect to barrier banks. The only ones that appeat necessary to be repaired, on account of the general undertaking, is the south wing of Green Bank and New Bank, the particulars of which are contained in the estimate. I find the marks left by the floods last winter, upon the south side of the Green Bank, to be 3 feet 11 inches above the surface of the lowest grounds there, that is, 6 feet 10 inches above the lowest grounds of Haldenby; and as this body of water was brought hither by a general overflowing of the level of Hatfield Chace, occasioned by the breaking of the banks of the river Idle, it would, in consequence, have laid almost the whole tract, now under consideration, under water, if it had failed. It, therefore, plainly appears, that this bank should not only be continued as a barrier, but strengthened and prolonged, as specified in the estimate for the safety of all the lands lying north thereof.

It comes now under consideration how far the drainage of the land of Eastoft, south of Green Bank, into the drains proposed for this level north of Green Bank,

can be complied with, with safety to the latter: and I am of opinion it may be done with perfect safety, provided the communication through Green Bank be made by a tunnel not more than 10 inches square, with a shuttle or stop sluice thereupon: for had such a tunnel been open and running during the flood of last winter, had also the drains and out-fall clough, specified in the following estimate, been then made, I am of opinion it would have been carried off as fast as it was uttered, without overflowing the level. But to take away all scruple, I would propose to lay the running of this tunnel under the following restrictions.

1st. It shall always be kept shut whenever the grounds to be drained thereby are overflowed by the waters from Hatfield Chace, or any other foreign waters, overtopping its barrier banks, and to continue shut so long as the water thereupon has any communication with any such foreign waters.

2dly. That it shall be kept shut at all other times, when the water in the mother drain rises within 9 inches of the surface of the low part of Haldenby Common, or within 6 inches of the general surface of the lands lying north of Green Bank, which may be ascertained by setting up stones or marks for that purpose.

The continuing of the barrier of this part of Eastoft beyond the limits specified in the estimate, the internal drains, erections, and maintenance of the tunnel of communication, I look upon to be private works, respecting this part of Eastoft Lordship, and, therefore, not comprised in the estimate; and as this scheme proposes nothing more than the carrying the mother drain to the boundary of each lordship, so as to give the waters thereof a proper out-fall, all other drains and internal works are considered as private works, and to be done at the particular expense of the respective proprietors.

ESTIMATE

For a Drainage, by a new Course, to Trent Fall. The Floor of the Sluice to lay 3 *Feet lower than the Floor of the present Clough at Hackensyke, that is, about* 1 *Foot* 8 *Inches above Low Water at Trent Fall, the Sluice to be* 10 *Feet Waterway, the Drain to be* 10 *Feet Bottom, to rise from the Clough towards Green Bank, which will be at the Rate of* 10 *Inches per Mile.*

	£.	s.	d.
To digging the pit for the clough or sluice, 19 feet deep, 35 feet mean width, and 100 feet mean length, containing 2463 cube yards, at 4*d*.	41	1	0
To 94 yards in length, from the Trent to *a*, exclusive of the sluice pit, 15 feet deep, 10 feet bottom, 50 feet top, containing 4700 yards, at 3*d*.	58	15	0
From thence to *b*, 387 yards, 12 feet deep, 10 feet bottom, 42 feet top, containing 13,416 yards, at 3*d*.	167	14	0
From thence to Hoggard's Lane, the end of Long Dyke Bank, at *c*, being, in length, 1150 yards, being 10 feet bottom, 36 feet 8 inches top, and, at a medium, 10 feet 3 inches deep, containing 30,796 cube yards, at 3*d*.	384	19	0
From thence through the rising ground of Adlingfleet, by the side of Long Dyke Bank, to *d*, length, 550 yards, 10 feet bottom, 36 feet top, and mean depth, 9 feet 7 inches, containing 13,628 yards, at 3*d*.	170	7	0
From thence to the north end of Willow Bank, *e*, 2550 yards long, 10 feet bottom, 29 feet mean width at top, and 8 feet 1 inch mean depth, containing 44,989 yards, at 2½*d*.	468	12	8½
From thence to Green Bank, by the letters *e f g h*, being, in length, 5496 yards, at a medium, 8 feet bottom, 18½ feet top, and 5¼ feet deep, containing 42,234 yards, at 2*d*.	351	19	0
To making the branch drain, *k l*, for communicating the waters of Whitgift low grounds with the main drain, being 690 yards long, 5 feet bottom, 13 feet top, and 4 feet deep, containing 2760 yards, at 1½*d*.	17	5	0
Carried forwards	1660	12	8½

	£.	s.	d.
Brought over	1660	12	8½
To repairing and strengthening New Bank, by way of a barrier, to defend the whole level against Reedness Common, so as to have 12 feet base, 4 feet top, and 4 feet high, containing 2500 yards in length, and, in the whole, 8889 yards, at 1½*d.*	55	11	1½
To repairing and heightening Green Bank, from the elbow southward, with an addition of 2 yards per yard running at a medium, being 1260 yards long, containing 2520 yards, at 2*d.*	21	0	0
To extending Green Bank about 100 yards further south, so as to render the same effectual, to be 12 feet seat, 4 feet top, and 4 feet high, containing 355 yards, at 1½*d.*	2	4	4½
Spade work	£.1739	8	2½

BUILDING.

To building a new sluice, of brick with stone facing, at Trent Fall, to be 10 feet clear water-way, including temporary dams, drainage of water, filling in the ground, and opening the sluice	500	0	0
For a road bridge, of brick, at Hoggard's Lane	40	0	0
To a ditto at Cow Pasture Lane	30	0	0
To a bridge for cattle, the middle of Haldenby Common	15	0	0
To a road-bridge, at the road leading to Whinsgate Bank	30	0	0
To a cattle-bridge, over the main drain, to communicate the two parts of Ousefleet Common	10	0	0
To a ditto over the branch drain	5	0	0
Building	£.630	0	0

ABSTRACT.

Spade work	1739	8	2½
Building	630	0	0
Supervising and contingencies, at 10*l.* per cent	237	0	0
Total,	£.2606	8	2½

THE QUANTITY OF LAND USED IN THIS UNDERTAKING.

	Cut. A.	R.	P.	Covered. A.	R.	P.
In Adlingfleet, Trentfield, and high grounds from Trent to point *d*	5	3	16	11	2	32
Adlingfleet low ground, from *d* to *e*	5	0	16	10	0	32
Willow Bank from *e* to *f*, there being space enough for the cut				2	0	0
From 5 to *m*, across Haldenby Common	2	1	16	4	2	32
Through Ousefleet Moor, &c. from *m* to *h* at Green Bank	4	0	0	8	0	0
The branch drain to Whitgift Moor, from *k* to *i*	0	2	20	1	1	0
	17	3	28	37	3	16

ABSTRACT OF THE ESTIMATE BY WAY OF HACKENSYKE.

The drainage by Hackensyke being estimated in the same particular manner, and the main drain being made 11 feet bottom, to the point *B*, near Coat's Bridge, in order to be an equivalent to the greatest length of time of running at Trent Fall; and being made from thence in two branches, one along the course *C, D, E, F, h*, which will drain Ousefleet, Whitgift, and part of Eastoft, and the other by the course *B, G, H, I, e, f*, which will drain Adlingfleet, Fockenby, and Haldenby, and also a second branch from *C*, by the Folly to Bought Gate, to make a proper out-fall for Eastoft waters.

	£.	s.	d.
The spade work	1833	4	10
Building	645	0	0
Contingencies, at 10 per cent	248	0	0
Total,	£.2726	4	0

LAND USED IN THIS UNDERTAKING.

	Cut. A.	R.	P.	Covered. A.	R.	P.
From Ouse to *A*	1	1	12	2	2	24
From *A* to *C*	8	0	35	16	1	30
From *C* to Green Bank	3	1	20	6	3	0
From *B* to *e*	2	1	20	4	3	0
Willow Bank, *e* to *f*, land enough for a cut				2	0	0
Branch from *C* to Bought Gate	1	0	0	2	0	0
	16	1	7	34	2	14

N.B. If Hackensyke Clough was made use of, as long as it will stand in its present form, and the drains dug of a proper width to admit of their being carried to a proper depth, when that Clough shall be obliged to be rebuilt on account of repairs, and lowered to the proposed depth.

	£.	s.	d.
The spade work will then come to	1691	3	10
The building to	145	0	0
Contingencies to	183	12	0
	£. 2019	15	10

And in case Ousefleet Clough was to remain as it does, without intention of lowering the same, the expense of proper drains, &c. suitable thereto, would amount to 1636*l.* 5*s.* 0½*d.*

Austhorpe, December 3, 1764. J. SMEATON.

DRIFFIELD BECK CANAL.

Estimate for making a navigable Canal from Driffield Beck to a Place called the Townsend, near Skerne, to be 16 *Feet at Bottom, and* 4 *Feet deep of Water, with Batters or Slopes according to the nature of the Ground.*

	£.	s.	d.
From Driffeld Beck to the beginning of Lewcop pasture, being 15½ chains length, mean depth, 6 feet 5 inches, batters, 1 to 1, the mean width at top will be 28 feet 9 inches, containing 5432 yards, at 2*d.*	45	5	6
Cross Lewcop pasture to the low corner of the Holmes, length, 12·3 chains, mean depth, 8 feet, the batters, as 3 to 3½, the mean width at top will be 34 feet 9 inches, the solid contents 6110 yards, at 3*d.*	76	9	9
From the low corner of the Holmes to 19·6 chains up the same to the point 1 in the map, mean depth will be 11 feet 8½ inches, and, being of a marly nature, the batters, as 3 to 4, the mean width at top will be 47 feet 2 inches, the solid contents, 17,712 yards, which, being hard to dig, may come to 4*d.*	295	4	0
Cutting to the middle of the Holmes	416	19	3
To enlarging the canal to 28 feet bottom, for 60 yards at the head, so as to take 2 boats in breadth and 3 in length, for convenience of unloading at warehouses, being there 12½ feet deep	16	13	4
To drainage of water, supervising, and contingencies	60	0	0
To the middle of the Holmes	493	12	7

FROM THE MIDDLE OF THE HOLMES, TO THE TOWNSEND UPON A DEAD LEVEL.

	£.	s.	d.
To carrying on the cut from the middle of the Holmes to the top of the Pighill, at P, being 31·10 chains long and 18 feet mean depth, the batters being 3 to 4, the top width will be 64 feet, the solid contents, 54,720 yards, at 4½*d.*	1026	0	0
From thence to the Townsend, being 23·5 chains length, mean depth, 20 feet, the batter, 3 to 4, the top width will be 72 feet, and the solid contents, 53,079 yards, at 5*d.*	1105	16	3
	2131	16	3

ESTIMATE FOR CARRYING THE NAVIGATION TO THE TOWNSEND BY A LOCK.

To the middle of the Holmes, the cut as before	416	19	3
A lock there, to rise 10 feet	600	0	0
To cutting from thence to the top of Pighill, 31·1 chains, at a medium 8 feet deep, batter, 3 to 3½, the top width will be 34 feet 9 inches, the solid contents, 15,443 yards, at 3*d.*	193	9	9
To cutting from top of Pighill to Townsend, being 23·5 chains, mean depth, 11 feet, batters, as 3 to 4, the width at top will be 45 feet 4 inches, the solid contents, 19,399 yards, at 3½*d.*	282	18	0
To making the dock as before	16	13	4
To bringing the water over the moor, suppose	15	0	0
To supervising and contingencies	150	0	0
Total,	£.1675	0	4

A DESCRIPTION

Of a Design for a Water-Engine, with a Comparative Calculation of its Abilities with the present Work, here follows :—

1, 1, 1, &c. represent the different parts of the frame-work; 2, 2, 2, &c. the parts of the water-wheel; 3, 3, its starts, of which more hereafter; 4, the main shafts' ends; 5, 5, the parts of the spur-wheel; 6, the wallowers; 7, the crank; 8, the crank rod, which communicates with the sub-regulator; 9 and 10, the communicating rod between; 9 the sub, and 11 the top-regulator; 12, 12, the arch heads to the top-regulator, to enable the buckets to make a perpendicular stroke, thereby enabling them to last much longer, go looser leathered, which will chamber or wear the barrels less, and lose less water. B, B, The chains to the bucket or piston rods; 14, 14, the bucket rods; 15, the bucket at the end of its rod in the section of the engine; 16, 16, and 17, 17, the face view of an engine together.

Now, whereas the circumstances attending these works, being almost peculiar to themselves, it requires, in order to render them more efficacious and serviceable, a particular or peculiar application; for though there are many stream and current mills, yet they go with a much more uniform motion, having nearly a certain quantity of back water, or strength of current; but as both these articles are so varying at these works, it requires a varying application of machinery, which is performed as follows: supposing the wheel to be at work with the greatest strength of tide, and going three turns per minute, then the sub-regulator to 9 has its fulcrum or centre of motion at *a*, which being 12 feet distance from *b*, where the crank rod lifts 2 feet 6 inches, and *b* being 6 feet from *c* in the sub, and *d* in the top-regulator, both lift 2 feet 9 inches; and as *d* is 10 feet distant from its centre of motion *e*, and 3 feet

from *f*, the chain's centre, and that of the barrel, therefore it makes 4 10½ stroke in the barrel; and when the wheels are at work with a great quantity of water, and move at a slow rate, yet there is sufficient momentum or force to raise much water; that force being always as the quantity of water multiplied into the velocity, so that, if there be three times the depth in water, and but one third of the velocity, that is, at the strength of the tide, nearly as much water may be raised as at strength of tide, in order to attain which it is necessary the engines should make a stroke proportionably longer, as they move fewer times, which will be obtained by moving the centre of motion *a* to *a a*; then, as *a a* will be 5 feet 6 inches from *b*, upon the crank-rod lifts 2 feet 6 inches, and *b* being 6 feet from *c*, therefore, *c* and *d* in the top-regulator are both lifted 5 feet 2¾ inches, and *f* the chain, and, consequently, the rod, 6 feet 10½, which is such a stroke made in the engine, which compensates in a great measure for the slowness of motion in the wheel; and all this is done in the most simple and lasting manner, by the application *g* at the end of the sub-regulator 9.

Now the comparative quantity of water raised by the present, and what might be raised, are as follows.

Having considered that though there are rules in mechanics for finding the quantity of water passing by in a given time, in a given section, by knowing the height of the water, but as that is very difficult but where the back water is very inconsiderable, and that the velocity of the water at its surface might be obtained, I rejected both in this case, and noted, that the three-ring wheel, at the strongest working, has gone 6⅔ turns per minute, which is nearly 25 feet diameter, and the new wheel in the same time made 5½ turns per minute, which is nearly 30 feet diameter; the whole space passed through in the minute, by each wheel, being 495 feet, this, with their charge of work on them, which must impede the water's motion at least ¼; therefore, if neither had been doing work, the water by going ¼ quicker, would have passed through a space of 619 feet per minute, which multiplied into 5 feet, which is about the depth the wheels go the strongest at, and the product in 12 feet from the width, gives 37,140 cubic feet of water expended on the wheel per minute, which is 3612 hogsheads; now as the wheels' revolution vary as 6⅔ to 5½, therefore the quantities raised must vary in like proportion, that I will reason upon the greatest quantities raised, which is 15½ hogsheads per minute. Now, as the difference or head of water is obtained by knowing the water's velocity, and that being known, as above, to be 619 feet per minute, it results, that the acting head to produce that must be 2 feet nearly; and I will suppose that the average height of all the water then raised by the four engines on the wheel did amount to 100 feet, that is, what some part of it might be raised higher, other like part discharged as much lower, and as 2 feet, the acting head, is contained five times in the height, we will suppose each hogshead to be 1 pound; then, suppose 3612lbs. (or hogsheads) expended on the wheel each minute, to be laid upon one end of a lever at 1 foot distance from the centre, it is evident it would keep in equilibrio 72lbs. at the other end, which is supposed to be 50lbs. on the other side of the centre, which 72 should be the number of hogsheads of water the wheel should keep suspended on the engines, it being the 50th part of the water expended, and fluids act in resisting in this kind as solids, on levers; but to allow amply for friction, &c. and to give the part of the machine sufficient motion, I will suppose, that nearly ⅓ of the 72 might be raised, (for in good machines, under favourable circumstances, ¾ of the 72, or 54 hogsheads, might be raised) which will be 24, and, according to my expectation, something more than that quantity, viz. 27 hogsheads per minute, for and by the

following reasons: as the wheels' floats are now no more than from 15 to 24 inches wide, they can produce no greater effect by their resistance than in proportion to their surface, for all the water that might be acting against them, extra to their present dimensions, goes over, rather to the impediment of the wheel than not, whereas, was this width increased, the power of the wheel would be increased likewise to a certain measure, but not if the other parts remained the same as now, for, as the wheels go now nearly the same pace as the water, therefore it is necessary to slacken the wheels' motion, and increase the engine's strokes, to resist the running water more, and thereby a proportionably greater quantity of water would be raised: then the starts 3, 3, should be thus constructed; they should all stand out 3 feet from the ring, each other having the boards only up to the ring, as may be seen by inspection, and the others having the boards within to 5 feet from the starts' end, as shewn; the method for doing them cheapest, most lasting, and serviceable, is to make the starts pretty wide, cut a slit in the middle, and slip the boards down it, and the whole is secured with a small bolt in the short, and two in the long ones, without iron plates; and up against each arm of the water-wheel to put boards 6 feet from the starts' end, by this method the wheel will be impeded getting into water less than if the starts were all 5 feet long, and the boards as broad, and nearly the same effect produced.

Now, by this provision, the wheel, when going so slow as 3 turns per minute, will so resist the water as to give it an opportunity to act so powerfully as to work 6 engines of seven-inch barrels in this manner at strength of tide, 3 turns the wheel, the wallowers going 3 to the wheels 1, makes 9, and the sub-regulator moving on the centre *a*, will produce 4 feet 10½ inches stroke, which multiplied into the 24 barrels will produce 27 hogsheads nearly per minute: and in less strength of tide, for some time before and after high water, the wheels will go from 1 to 2 turns per minute, by means of the large surface of floats, I will call it 1½ turns, and then the sub-regulator will move on the centre *a a*, which will produce 6 feet 10½ inches stroke in the engine barrels, and that in the 24 barrels will give 19 hogsheads per minute.

3 rings at 6⅔ turns rise 15 hogsheads per minute.	This design at 3 turns to rise with 4 feet 10½ inches stroke, 27 hogsheads per minute.	Ditto at 1½ 6 feet 10½ inches stroke, 19 hogsheads per minute.

The following is an examination of the said engine, in answer to the above.

EXAMINATION

By JOHN SMEATON of a Design for a Water-Engine communicated by Dr. BIRCH.

THIS design, though not so mentioned, appears evidently intended for London Bridge water-works, and, therefore, as such I shall consider it; and though the unknown inventor of the design has shewn evident marks of genius, and a laudable attempt of improvement, yet as I cannot agree with him in the whole of his reasoning about it, I think it necessary to give my opinion with that freedom that becomes me in a matter wherein I am consulted, and, therefore, have a right to expect that what I may say will not be considered as the effects of a desire to criticise, but to do justice, where my opinion is desired in the way of my profession.

In the first place, I agree with the inventor in the use of arches and chains at the end of the regulator, having ordered the like in the engine lately erected for the West Ham Company at Stratford.

2d. I also agree with him in thinking the circumstances of these works are so peculiar to themselves as to require peculiar applications, in order to bring them to perfection, and that it is to be wished that means could be found out by which the load could be occasionally varied, in proportion to the variations of velocity and power, without rendering the engines complex, and more liable to be out of order. I also agree with him, that by means of a movable centre, to what he calls a sub-regulator, the stroke of the engine may be varied, and, therefore, the power of the engine in the same proportion; but I can by no means agree with him in the use to be made of this machinery; he supposes that when the tide is high, and the current moves slow, that the body of water being then great, the superior quantity will be equivalent to the want of velocity, so that if there be three times the depth in water, and but $\frac{1}{3}$ of the velocity, that is at the strength of tide, nearly as much water may there be raised, as at the strength of tide.

But had the inventor computed the head or acting column of water necessary to produce $\frac{1}{3}$ of the velocity, by the same rules that he finds 2 feet necessary to produce the velocity of 619 feet per minute, he would have found $\frac{1}{3}$ of 619, viz. 206 feet per minute, produceable by a head or column $2\frac{2}{3}$ inches, which is only $\frac{1}{9}$ of 2 feet, it being well known that the square of the head is as the velocity. Hence it appears, that as the acting column is only $\frac{1}{9}$ of the height, the impulse or pressure upon the same quantity of surface of float-board will be $\frac{1}{9}$ also; and even if we suppose the surface acted upon to be increased in proportion to the depth of water, which is not the case, (in the construction before me) the whole impulse or pressure upon the wheel can be only $\frac{1}{3}$ of what it would be at strength of tide; so that if the wheel is loaded as here proposed, near high water more than at strength of tide, in the proportion of 4 feet $10\frac{1}{2}$ inches to 6 feet $10\frac{1}{2}$ inches, which is as 5 to 7 nearly, it is very probable that the wheel, instead of doing *nearly as much as at the strength of tide*, would stand quite still, and the benefit of the slow motion, that would otherwise take place, quite lost: in short, it is like a horse moving slow with his load in consequence of having carried it far, and being wearied therewith, to load him harder in order that the greater burden may compensate for the slowness of his motion. It, therefore, plainly appears, that if any good is to be expected from this sliding motion, it must be by adjusting the longest stroke to the strength of tide, that as the tide grows weaker the stroke may be shortened, and the power of the engine adapted to the power to move it.

In regard to the machinery of the sliding centre, as it is not perfectly made out, I am enabled to say the less upon it; but in an engine that works both ways, that is, lifts up as much as it pulls down, any shake in the centre work will be very detrimental to its motion, and occasion it to be frequently out of order; and further, I conceive it difficult so to contrive it as to be, and keep lastingly steady, especially as in the present engine, in some cases, the action of the crank upon the centre will be greater than its action upon the piston, as 11 to 4; but supposing the difficulties in the execution to be conquered, still this must happen, that as the barrels in moderate space of time will sensibly chamber, and the middle part of the barrel, so far as the short stroke reaches, will be always in wear, but that part above and below the limits of the short strokes only in wear when the long stroke is used, it follows that the barrels will chamber unequally. An engine will go very well with its barrel a good deal chambered; in short, they are seldom rebored so long as a new leathered piston can

be got in at the mouth so as to fill in the chambered part, but then as they chamber nearly equal, and the stroke remains the same, that of the barrel in which the piston moves is still nearly a cylinder; but, in the case of unequal strokes, the piston would be obliged to move through a space alternately narrower and wider, which would cause it to work very hard. Again, as it might be sometimes for some days together in neap tides that the long stroke would not be made use of, the extra parts in that time would in iron barrels grow rusty, and when used again would not only cause the engine to go still harder, but also destroy the leathers. This last inconvenience would indeed be remedied by brass barrels; but where the charge and difficulty is great, and the effect not greatly superior, an invention so circumstanced is less eligible. This thought of altering an engine's power by a different length of stroke is not new to me, having had the same thought ten years ago; but while I was contriving the machinery necessary to perform it, the objection of the unequal chambering of the barrels occurred to me, which made me lay it aside, though cases have occurred to me in which it would otherwise have been applicable and useful.

It now comes in place to inquire into the general proportions and adjustments of the engine, to work at strength of tide; and I agree with the inventor, that a wheel of large diameter will wade in a great depth of water to more advantage than a moderate one; that a great breadth of float-board will resist the current more than a narrow one, and, consequently, give more power to the engine; and that the wheels, at strength of tide, may, with advantage, be made to move with a greater load than they do at present, but advantages carried to extremes often prove disadvantageous, according to the proverb, things in a middling way are frequently best.

With respect to the water wheel's height, that a wheel of 30 feet will get better through the water when wading at a given depth than one of 30 or 25 feet, is already allowed; but then as it moves proportionably slower, what is lost in number of revolutions of the first mover (in order that the same quantity of water may be raised) must be gained in the second; so that the same spur-wheel will act on a less wallower, or a larger spur-wheel acting upon the same wallower, produces a proportionably greater strain or twist upon the axis of the water-wheel; again, if more engines are put on, or with longer strokes, or both, the strain will be greater in proportion to the increase of water drawn thereby; if, therefore, the 25 feet wheel's axis goes $6\frac{1}{2}$ turns for the proposed wheel's 3, the strain upon the old axis to that of the new will be as 3 to $6\frac{1}{2}$, supposing the same work done by both; but if the work done is more in the proportion of 15 to 27, the number of hogsheads supposed to be raised by each, or, as I calculated it, 13·2 to 26·7, the compound proportion will be 39·6 to 17·8; that is, the strain or twist upon the new wheel's axis, when at its lesser stroke, will be $4\frac{1}{2}$ times greater than that of the present 25 feet wheel; so that it is much to be questioned, whether an axis of 3 feet diameter, (which I apprehend to be that here proposed) or indeed any timber that can be got, will bear the strain so as to be sufficiently lasting.

The size, disposition, and machinery of the floats I think is very good, but I think a smaller number would do as well in this situation: as to the fall proposed to the breast of the wheel, I think it not only expensive and difficult here to lay, but useless in this place on tide of ebb, and detrimental to the action of the wheel on tide of flood. The proposition of increasing the number of barrels I can by no means approve, for either another crank must be added, or there must be six barrels to each engine, either of which will be attended with inconveniences, more complication, and more increase of friction, than is necessary.

Lastly, with respect to the comparison of the effects of the old and new engine, I

look upon it as a matter of certainty, from observation, that the 25 feet wheel moves $6\frac{1}{3}$ revolutions at strength of tide, and, therefore, that its mean circumference moves through a space of 495, or, as I make it, of 497 feet, and, in this case, bonâ fide raises 13 hogsheads of 63 ale gallons each per minute; but what is the velocity of the water driving the wheel, by no means appears, we are sure the natural velocity of the water must be greater than the wheel, but whether it be $\frac{1}{5}$, $\frac{1}{6}$, $\frac{1}{4}$, $\frac{1}{3}$, or $\frac{1}{2}$ by no means appears; the number 619 therefore, expressing the velocity of the water per minute, cannot be considered otherwise than as conjectural, and, consequently, the number 3612 hogsheads expended per minute, deduced therefrom, must be conjectural also: the acting head to produce 619 feet velocity is 1 foot 8 inches nearly, not 2 feet as here supposed; but if 619 is conjectural, the head 1 foot 8 inches must be also conjectural.

The mean height to which the water was supposed to be raised, viz. 100 feet, I apprehend is also conjectural, since it rises higher or lower in the stand-pipe, as there are a greater or less number of cocks open upon the mains: now if 100 be divided by 1 foot 8 inches, the quotient is 60; but as both the divisor and dividend are conjectural, the quotient will be still more so, and this being again a divisor to the conjectural number 3612, the quotient, which will be 60, will be still more conjectural; but supposing the number 619 and 100 both right, or nearly so, then the number of hogsheads equivalent to the power will be 60; but still there remains a difficulty what proportion of this quantity we must take for the neat performance of the engine; few or no engines that I have seen have yielded $\frac{1}{4}$, most fall short of $\frac{1}{2}$, and the present engine less than $\frac{1}{4}$, but more than $\frac{1}{5}$, that is, in case we are right in the two numbers before mentioned, because if we are not, we still remain uncertain what the effect thereof is, in proportion to the power producing it. All, therefore, that we can fairly conclude is this, that a greater quantity of float-board will give a greater power, and a greater capacity of pumps will raise a greater quantity of water, provided we do not overload our power, or break our tackles by overstraining.

GASCOIGNE ON RAISING WATER OUT OF SHIPS.

Examination of Mr. Gascoigne's Proposals for Raising Water out of Ships. By John Smeaton.

Respecting that part of his proposal which consists in applying the forcing pumps to the raising of water out of the hold of a ship, by which means he is enabled to place the most essential parts of his machinery below the water line, is a merit that will be obvious to every seaman; I shall therefore not take up time in saying more about it than that it seems worth attending to, in case the conveniency of a ship will admit its execution, and the more especially as I am very certain, from experience, that as much water may be raised in this way as any other. But in regard to the great preference Mr. Gascoigne gives his pump above the chain pumps, in point of quantity delivered, and in point of power wherewith he proposes to work it, I can by no means agree with him. He proposes to raise 86 tons of water per hour to the height of 22 feet, by four men; whereas he gives us to understand, that the common chain-pump requires 14 men to raise 60 tons per hour to the same height; a very surprising

difference indeed! In order to prove this, he has recourse to calculation, and, as a ground-work, make this supposition, that four men will turn round the winch or handle of his machine 60 turns per minute, in which case, as this will produce a stroke of 1 foot long in four pump-barrels of 6 inches diameter each, this will necessarily produce a certain quantity of water per hour, which he calls 86 tons, but which, according to my computation (supposing none lost) is scarcely 84; but this I pass over: now if, on the other hand, we suppose that four men cannot turn round the winch 60 turns per minute, then the whole computation falls to the ground. He endeavours further to support himself by a comparison of the friction of his engine with the chain-pump; in order to this, he calculates the number of frictions in his machine, and gives each of them a determinate value, viz. four pounds; he also calculates the number of frictions in the chain-pump, and calls each of them five pounds; but as this is a method of computation totally new to me, and as he has given no sufficient reason why he calls a friction in one machine four pounds, and in the other five, nor why he might not as well have called them four ounces each, or 40 pounds, as best served his purpose, I shall not take up any more time in pursuing him any farther in this road, but shall endeavour to set the whole in clear light.

Desaguliers, in the second volume of his Experimental Philosophy, has taken a good deal of pains in finding out a kind of land-marks to guide us in those kinds of pursuits, and to enable us to value the pretensions of projectors in the art of raising water; and he has told us, that the mean strength of a man, when applied to the best kind of pump that has been yet in use, amounts to no more than the raising one hogshead of water in a minute to the height of 10 feet; for my own part, I have made a variety of machines and many observations of this kind, but never yet found the value of men's strength at a medium equal to what is set down by Desaguliers, unless they are supposed to work in haste, or distress, for a few minutes; however, as it is more favourable to Mr. Gascoigne's proposal, we will for the present suppose the performance of men equal to what is stated by Desaguliers, viz. one hogshead per minute at 10 feet high, that is, at the rate of 60 hogsheads per hour.

Now by the unalterable laws of hydrostatics and mechanics, if a man can only raise 60 hogsheads 10 feet high per hour, he can only raise 30 hogsheads to 20 feet, and only $27\frac{3}{11}$ hogsheads to 22 feet in an hour, by the same rule of proportion. Now $27\frac{3}{11}$ hogsheads, consisting of 54 ale gallons, as supposed by Desaguliers, makes $7\frac{1}{8}$ tons nearly, that can be raised by one man per hour, to the height of 22 feet, and consequently that $28\frac{1}{2}$ tons per hour is the utmost that can be raised by 4 men, instead of which Mr. Gascoigne proposes to raise 86.

If we examine what he has stated concerning the chain-pump, by the same rule, we shall find its pretensions more modest: he supposes the chain-pump to raise 60 tons per hour by 14 men; now if $7\frac{1}{8}$ tons per hour is all that can be raised by one man to the height of 22 feet, 14 times $7\frac{1}{8}$ tons equal to $99\frac{3}{4}$, or in round numbers 100 tons, is the utmost that can be raised by 14 men, instead of which the chain-pump only raises 60; so that here it falls considerably short of the mark. However, we may hence conclude, that as the chain-pump is deficient only 40 parts in 100, that all the pump-work that can be contrived will never exceed the present chain-pumps above the proportion of 60 to 100; whereas, men and quantity considered together, Mr. Gascoigne proposes to improve upon the chain-pumps in the proportion of 60 to 301, which is the number of tons that ought to be raised by 14 men, according to Mr. Gascoigne's method. For my own part, I believe that the friction naturally attending the chain-pump will never admit its performance to be quite equal to what can be done by other known kinds of pumps; but as it is capable of some

improvement, I am clear that it might be made to raise 75 tons per hour instead of 60, and with more ease to the same hands.

It may, perhaps, be imagined that there is something in Mr. GASCOIGNE's machine that is new, and preferable to all those that may be made trial of; but I beg leave to observe, that it differs in no essential point from the crank machines commonly made use of for raising water by water or horses for gentlemen's seats, brewers, distillers, dyers, &c. though not that I know of applied to ships; and in point of raising water, I look upon it not quite so well adapted as the machine he describes, and calls the store-pump at Portsmouth, because a three-necked crank works more equably, and is attended with less friction than four; and in regard to his application of an air vessel, though useful on many occasions, is of no use on the present; it must, however, be allowed, that the form of the pump in store at Portsmouth is much more cumbersome, and less adapted to the convenience of a ship, besides the inconvenience of some of its essential parts being above the water line. I apprehend Mr. GASCOIGNE's machine capable of some improvements, by which it might be made to raise about 80 tons an hour with 14 men, instead of raising 86 tons with four men, aud if its situation will be agreeable to the convenience of ships, may be used to a very good purpose.

LONDON, January 20, 1765. J. SMEATON.

BRISTOL HARBOUR AND CANAL.

Proposals for laying the Ships at the Quay of Bristol constantly afloat, and for enlarging this part of the Harbour by a new Canal through Cannon's Marsh, by JOHN SMEATON.

1st. IT is proposed to keep the water in the quay and new canal to the constant height of the 15 feet mark upon the lowermost marked staff upon the quay next the Avon, and clearing away 2 or 3 feet of the mud there laying, to make from 17 to 18 feet water.

N.B. The 15 feet mark is about 6 feet below the top of the quay, and about 4 feet below the spring-tide high water mark of the 24th and 25th of January, 1765, which, though not the largest, were nevertheless accounted considerable tides.

2dly. It is proposed to dig the new canal as far as the sluices, so deep as to make 18 feet water therein at the said proposed level, and to make the same at least 100 feet wide in the clear.

3dly. To drop the tail of the new canal into the river Avon at the bottom of Cannon's Marsh just above the Glass House.

4thly. To construct two separate sluices, one as near as conveniently can be to the river Avon, upon the tail of the canal, the other at the distance of 400 feet from the former, further within the canal; both these sluices to be furnished with two pair of pointing gates, one pair in each sluice pointed to land, the other to seaward. The width of the chamber, or space intercepted between the two sluices, to be 60 feet, and the width of the sluices to be capable of taking in the largest ships that use the port, which I suppose will be done by an opening of 30 feet wide.

5thly. The threshold of the upper sluice to be laid at the depth of 18 feet below the constant water that is even with the bottom of the canal; but the floor of the chamber between the two sluices, as well as the threshold of the lower sluice, to be

laid as low as the bottom of the river in the shallowest place, below the tail of the canal.

6thly. These things being executed as before mentioned, the present mouth or opening of the river Froome into the Avon to be stopped up by a solid dam of earth, furnished, however, with such draw-hatches as may be necessary to assist the hatches in the gates of the sluices in discharging the freshes of the river Froome in rainy seasons, but yet so as to make a communication for all kinds of carriages from the Back and Quay down alongside of the new canal between the same and the river.

7thly. The whole of the new work to be wharfed with stone, so as to form quays or such other conveniences as shall be found necessary.

8thly. To erect draw-hatches at the new bridge at the head of the quay, capable of retaining the water behind them when the water in the new canal and quay is let off.

9thly. To have the command of the hatches, and to erect new ones, if necessary, upon the pond of Newgate Mill.

N.B. By the constructions above proposed, Tom's Dock and Bridewell Mill will be rendered useless, but Newgate Mill will be benefited thereby.

OPERATION OF THE FOREGOING CONSTRUCTIONS.

When the tide is out, the water of the canal is proposed to be retained by the land-gates of the upper sluice, all the rest being open on tide of flood. As the vessels come up, they go into the chamber between the sluices, where they always find equal water with that they came up with, which chamber is capable of holding eight ships, or four ships and six troughs, at the same time; here they wait at spring tides till the flood in the chamber is upon a level with the canal, at which time the sea-gates of the lower sluice are put to, which prevents the tide's water flowing into the canal; the land-gates of the upper sluice are then opened, and the vessels proceed to their births.

Then the large vessels that are going down, that require to depart at high water, are brought down into the chamber while the tide is flowing; the sea-gates of the upper sluice being then put to, and the hatches of the sea-gates of the lower sluice drawn, the chamber fills to the level of the tide in the river, and the sea-gates of the lower sluice are opened; and if any deep vessels are arrived after the tide had rose to the level of the canal, they may now be taken in, where they wait all together till high water, when the outward bound depart, with the first moment of the ebb, and the inward bound wait till the tide has sunk to the level of the canal; at which time the land-gates of the lower sluice are put to, and the sea-gates of the upper sluice are opened, which gives those ships leave to go to their births, and at the same time to take in such of the vessels as are outward bound, and can go down with the remainder of the ebb, after the water is fallen to the level of the canal; which vessels being brought into the chamber, the land-gates of the upper sluice are put to, and the hatches of the land-gates of the lower sluice drawn, by which means the water in the chamber is reduced to the level of the tide in the river; the land-gates of the lower sluice are then opened, and the vessels depart, leaving the sluice in the same position as we found it.

Hence it appears, that two sets of vessels may go up and two down in one tide, when the spring tides rise above the level of the canal's water, and that without the admission of any tide-water into the canal, except what happens to get in by the disturbance of the water by the passing of vessels, which, as it will lodge near the upper

sluice, the greatest part will be drawn through the hatch of the land-gates of the upper sluice; which ought to be drawn at low water to let off the water accumulated in the canal and quays by the currency of the river Froome, and to scour the chamber and the lower sluice from the mud left by the tide.

At neap tides the vessels inward bound come into the chamber as before, as soon as they have water, and wait all together till high water, which being below the level of the canal, the land-gates of the lower sluice are then put to, and the hatches of the land-gates of the upper sluice drawn; by which means the chamber will fill to the level of the canal, and as the land-gates of the upper sluice may then be opened, the vessels may proceed to their births, and those that are ready to go down may haul in; after which the land-gates of the upper sluice being put to, and the hatches of the land-gates of the lower sluice drawn, the water in the chamber is then reduced to the level of the tide in the river; the gates of the lower sluice may then be opened, and the vessels proceed with the tide.

When water is plentiful in the river Froome, the vessels going up at neap-tides may be penned through the chamber, by drawing the hatches of the upper land-gates some time before high water, which will afford more time for the vessels going down to get into the chamber before the tide is much abated; otherwise it will be most advisable, that after the vessels going up are gone out to their births, to keep the water against the land-gates of the lower sluice till the next tide, when all the vessels going out will have time to get into the chamber, and be ready to go out all together at high water. By this method of passing, the vessels inward bound one tide and outward bound the next, they will all have all the benefit of the full tide, and the whole of the water expended in twenty-four hours will be only so much from the canal as is necessary to fill the chamber from the level of high water to the level of the canal; and I apprehend the season is seldom so dry, but that the currency of the Froome will, at an average, replace this to the body of water contained in the new canal and quays in twenty-four hours; but, by way of further supply, as no water will be wanted from the canal to pass the vessels in spring tides, an accumulation of 1 foot may be retained without prejudice, which, upon so large a surface as will be contained in the new canal and quays, would alone be nearly equivalent to the water expended in the chamber for passing the vessels, according to the last-proposed method. Yet, as a sheet anchor, the pond of Newgate Mill may be had recourse to, upon paying an equivalent; but which, from the reason already stated, I do not apprehend can be wanted above once in seven years.

As by this method the tide-water will be almost wholly excluded, there will not be a need of often scouring; but, when this is done, the hatches proposed at New Bridge will be of use, and the hatches upon Newgate Mill Pond will be still of further use; but I do not apprehend this operation will be needed above twice, or at most four times a year.

OBSERVATIONS.

1st. A power of diverting other streams into the river Froome, upon necessary occasions may be of use, and of making reservoirs for water.

2dly. The sea-gates of the upper sluice are to have no draw-hatches, which will effectually prevent the ships from penning into the canal with the tide's water.

3dly. By these constructions, whenever there is water to bring up a ship to the tail of the canal, she is always enabled to get to the quay.

4thly. The ships being kept constantly afloat, the river Froome will, of itself,

birth a great number, and the new canal will birth twenty-four ships, besides leaving a sufficient passage; but, by making it wider, will birth a greater number; every ship's breadth in width makes an addition of twelve births.

5thly. The expense, as near as I am at present enabled to calculate the same, will be as follows.

	£.	s.	d.
To digging	6555	0	0
Quay walling	4887	0	0
The two sluices	8000	0	0
The dam and hatches across the present mouth of Froome river	1000	0	0
The hatches at New Bridge and upon Newgate Mill Pond	600	0	0
Contingent expenses being supposed	3958	0	0
	£.25,000	0	0

Exclusive of purchase of lands and damages to Bridewell Mill and Tom's Dock.

Bristol, January 26, 1765.

Bristol, January 26, 1765.

At a numerous meeting of the merchants of the city of Bristol, this day held, John Smeaton, Esq. having presented to them a scheme and plan for laying the ships at the quay of Bristol constantly afloat, and for enlarging that part of the harbour by a new canal through Cannon's Marsh, it was unanimously voted, that the thanks of the gentlemen present be given to Mr. Smeaton for his plan now offered, and for his diligence and attention in this matter.

THO. SYMONS, Clerk.

Austhorpe, December 31, 1766.

Having perused and considered the plans this day laid before me relative to Bristol Harbour,* I am of opinion, that the uppermost and lowermost where the sluices are made out of the river, and the dam upon the channel of the river, are more practicable and eligible than the middle scheme, where the whole is done within the bed of the river, and, provided the expense of the execution of either of those schemes is no objection, there is no other material one that occurs to me; and respecting the eligibility of the upper or lower scheme, as there is no difference but what relates to convenience and expense, this is a proper subject for the determination of the merchants of Bristol. But whichever of these schemes are executed, I advise, if two passages are made, to keep them entirely separated by a middle wall, and to raise these walls and gates at least 5 feet higher than the crown of the dam, especially at that end next Bristol.

J. SMEATON.

PORTABLE FIRE ENGINE.

Description of a Portable Fire-Engine, invented by John Smeaton, F.R.S, at the Instance of the Right Honourable the Earl of Egmont, 1765.

No. 1. Shews the ground plan of the walls for supporting the engine, which is supposed to be necessary, in order to keep the several parts of the machinery from settling under the weight, wherein,

* Designs of Mr. Champion, who came with them into Yorkshire in company with Mr. Symons, clerk of the company.

A B is the pit or shaft. *C C*, foundation walls on each side of the pit, for supporting the fore part of the engine-frame across the pit. *D D*, a foundation wall in like manner, for supporting the back part of the frame. *E E*, walling under the boiler. *F* shews the centre of the boiler. *G*, the place of the cylinder. *H*, the main pump. *I*, the jack-head pump. *K K*, the ash-hole.

No. 2 contains elevations of the engine, viz., an end and side view thereof, when put together, wherein the same letters as are in the plan refer to each.

A B is the pit or shaft. *C C*, the upright of the foundation walls on each side of the pit, for supporting the groundsill *c* across the pit, upon which one side of the engine-frame is raised. *D D*, the foundation wall for supporting the groundsill *d*, upon which the other side is raised. *E*, foundation wall, for supporting the boiler, and forming the ash-hole. *F* is the boiler; *f*, the fire-door; *g*, the chimney; *s*, the steam-pipe; *p*, the puppet-clack; *v*, the feeding-pipe funnel; *z*, the man-hole. *G*, the cylinder. *H*, the main pump-spear. *I*, the jack-head pump, by the continuation whereof *k*, *k*, *k*, the water is conveyed into *L*, the injection-cistern. *M*, a wheel serving instead of the great beam; *m*, a rim of a smaller diameter, attached to the former, for working the jack-head pump *I*, and plug-frame *Q*. *a a*, pullies to bring their chains into a convenient place for working. The wheel is stopped at the end of its intended stroke, which is to be $6\frac{1}{2}$ feet, stop and stop, by means of the two iron fids *b b*, which, reaching out on each side of the great rim, stop against two strong iron pins *e e*, which are fixed into a cross-beam *S*, framed into the piece *T*, and the whole firmly bolted together, as shewn in the design; *N* is the injection-pipe, *n*, the injection-cock, and *x*, the piston water-cock. *O* is the hot-well. *R*, a stage for the person to stand upon, who hands the engine. *P P* are the two main-beams or sleepers, upon which the cylinder is seated upon its bottom, and bolted down; the whole is kept from springing or flying off by the iron strap *q*.

N.B. The waste water-pipes are omitted to prevent confusion.

No. 3, Fig. 1, shews a section of the boiler, cylinder, and pipes, with the working-gear, to a larger scale, the whole being divested of the framing, in order to render every thing more distinct.

N.B. The boiler is supposed to be turned one quarter round, from its true position, as in No. 2, in order that the most material parts may be brought into one view. It is also to be noted, that every vessel or pipe is supposed to be cut right through the middle, in order to shew the contents, and not that the section is confined to any particular plane; but, for the more perfect explaining of the principal figure, it will be best to begin with the little plan marked Fig. 2, wherein

A B C D is a plan of the cylinder bottom, bolted down upon the two main beams *A B* and *C D*; the dotted circle *E F* shews the extremity of the bottom flanch of the cylinder, and the circle *G H*, the diameter of the cylinder within; the hole *I* answers the steam-pipe and regulator; and the hole *K*, the eduction or sinking-pipe, and the circle *L M*, its flanch; the circle *N O* shews the size and position of the regulator-plate, and the dotted circle *P Q*, the size of the receiver, in which the sliding valve of the regulator *R* works, and in this position is open; *S T* is the lever by which it is worked; and when that is brought forwards into the position *S V*, then the valve covers the aperture of the regulator.

EXPLANATION OF FIG. 1.

A is the boiler, and *B* the fire-place, which is intended to be of a spherical figure, of cast iron, and intirely within the boiler; the coals are to be introduced by the large pipe or opening *C*, and the smoke carried off by the curved pipe *D*; and, in

order to promote a sufficient draft, the iron funnel *E* is added. The ashes fall through the grate *S*, and wide pipe *F*, into the ash-holes below. The whole being joined to the boiler by proper flanches, as is shewn in the figure, and always covered with water, as will be known by the two gage-cocks *a*, *b*.

Though it is expected that a small force of fire thus applied will keep the engine going, yet as that force cannot be wholly exhausted within the compass of the boiler, it is proposed to surround the curved pipe *D* with a copper vessel, somewhat adapted to the shape thereof, as represented in the figure, in which it is proposed to bring the feeding water, which will hereby be prepared to a greater degree of heat than if brought immediately from the hot well into the boiler; into which it is to be introduced by the little hole at *c*.

The bars of the grate *S* are intended to be cast in a loose ring, capable of being taken out, and replaced when occasion requires.

T, a cock for emptying the boiler when it wants to be cleaned. *G* is the cylinder into which the steam ascends from the boiler, by the pipes *d e H I*, of which *d e* are the copper, and are disunited at *f*, for the sake of taking the engine easily to pieces; and are joined by first bending a piece of lead round the joint, and then wrapping them with cloths and cords, as is common in great engines. *H* is the receiver for the steam, of cast iron, containing the regulator-valve; and *I* is the steam-pipe, by which the steam passes to the cylinder when the regulator-valve is open; which, in the present situation of the engine, it is supposed to be, in which case the piston *K* will begin to return. *L* is the snifting-clack, at which the steam at this instant blows out. *M* the injection-cock, which is now shut. *N*, the injection-pipe, which brings down the water from the cistern above. *O*, that part of the injection-pipe that conveys the water into the cylinder, when the injection-cock is opened, and which terminates in a cap that directs the jet of water perpendicular; the injection-cap is in the centre of the cylinder, but as part of the termination of the injection-pipe lies behind the steam pipe *I*, it hinders the complete view thereof; the other parts will, perhaps, be better described by an explanation of the operation of the engine.

OPERATION OF THE ENGINE.

To render this explanation intelligible, it is to be premised, that the plug-frame *P*, which moves up and down with the piston, but with a different velocity, according to the diameters of the two wheels (*M* and *m*, No. 2), is furnished with pins, which lie in four different planes, answerable to four different detents or arms of the working gear: the pin 3 lies upon the fore side; the pin *g* lies in a mortoise, which divides the plug-frame into two parts, the pins *S*, 1, 2, lie upon the far side, and the peg *p* stands in the place of the plug-frame, upon the further cheek. Now, when the piston is risen as high in the cylinder as its stroke is intended, the pin *g* having met the arm *h* of the tumbler *i k*, oversets it into the position *i m*; so that the point *k* moving into the place of *m*, the regulator-valve is shut, by drawing the rod *k o*, which takes hold of its lever towards the plug-frame; and at the same instant the peg *p* rising so as to lift up the catch *q*, the beak of the faller (or *F* as it is commonly called) marked *r*, is disengaged therefrom, and the weight *w*, by descending into the place *v*, carries the fork *x* along with it, and therewith the lever that turns the injection-cock into the place *y*, and whereby that cock is opened, the jet played, and the steam reduced into water (or condensed, as it is commonly called), hereby a vacuum being produced within the cylinder, the pressure of the air causes the piston to descend, and in descending, the peg *S*, on the far side, meeting the faller at *t*, carries it down to *z*, which shuts the injection-cock, and

also hooks the beak behind the catch *q*, and thereby the tail *t t* becoming parallel to the plug-frame, the pins succeeding the pin *S* retain it in the same position, the piston still descending till the peg 3 on the fore side, laying hold of the arm 4 of the tumbler at *n*, thereby brings back the regulator into its present position, and the further descent of the piston is stopped by letting in the steam.

The water thrown in by the injection at each stroke, and also generated from the steam, is evacuated while the piston is rising, by means of the eduction or sinking-pipe, and valve *Q*; this pipe, lying exactly behind the steam-pipe *I*, is thereby, in a great measure, hid; the steam-pipe is carried several inches above the bottom of the cylinder, to prevent the injection water from running into the boiler; but the eduction-pipe rises no higher than the bottom, in order to lead the water into it; and as the bottom of the cylinder is commonly elevated from $1\frac{1}{2}$ to 3 feet above the valve at the bottom of the eduction-pipe, commonly called the horse-foot valve, the pressure of this column of water opens the valve, and makes its way into the cistern *R*, called the hot well; but when the vacuum is made, this valve shuts, and, being immersed under the surface of the hot-well water, is thereby kept air-tight.

As there is a considerable quantity of air lodged in water, when in its natural state, which separates itself by boiling, and, in some degree, by considerably heating, it follows that a quantity of air passes along with the steam into the cylinder, and that a further quantity escapes from the injection water, by being considerably heated with the steam; and though air is capable of being considerably expanded by heat, and contracted by cold, yet the degree is so very much less than that of steam, that if the air generated at each stroke was not evacuated, it would quickly render the vacuum so imperfect, that the piston would stop in the middle of its descent. Now, as the air will be lodged, when the piston is down, between the surface of the injection water lying upon the bottom of the cylinder and the piston, in order to get rid of it, the snifting-clack *L* has been happily applied; for, on the first rush of the steam into the cylinder, the piston not being instantly put into a contrary motion, the steam, finding a passage at the snifting-clack for a small space of time, blows out thereat, and therewith carries the whole or the greatest part of the air generated at each stroke, so as to prevent its increase beyond a certain degree.

The surface of the hot-well water being in general from 3 to 5 feet higher than the surface of the water in the boiler, this height of column is sufficient to force its way into the boiler, though resisted by the action of the steam within, when sufficiently elastic for use; it therefore finds its way down the feeding-pipe 5, 6, through the feeding-cock 7, which is opened so much as is found necessary for supplying water to the boiler as fast as it is consumed in steam. It is evident, that whenever the repellancy of the steam within the boiler is not too great to suffer the surface of the water in the feeding-pipe to be below that of the hot well, that the boiler will feed by the passage of the water into the pipe; but whenever the repellancy of the steam is such as to keep the water in the feeding-pipe above that point, that then the water will revert into the hot well; but as the repellancy of the steam within the boiler is alternately greater and less, as the regulator-valve is shut or open, during each stroke of the engine, it follows that the boiler may feed while the cylinder is drawing the steam from the boiler, and revert while the piston is descending. In order, therefore, to make this matter safe, and at the same time to bring the engine into as small a compass as possible, the valve 8 is placed in a little box in the hot well, to prevent such a reversion. It is necessary to continue the feeding-pipe, as usual, considerably above the hot well; for as the water is in a vibrating state within this pipe, according to the variable repellancy of the steam within the boiler, this extension is to prevent its frequently overflowing; for it is

necessary to be open at the top, otherwise the steam generated therein would prevent its feeding at all, or very irregularly.

N.B. The hot well is, in this view of the machinery, represented considerably larger than it is; for supposing the boiler turned a quarter round while the feeding-pipe 5, 6, falls directly behind the puppet-clack 9, as shewn in the general elevation, the hot well will then be shorter by half the diameter of the boiler.

The puppet-clack 9 has no other use than being loaded with a certain weight, in proportion to its size, that whenever the repellancy of the steam in the boiler is greater than to lift up this clack, it evacuates without bursting the boiler, which it otherwise might do, and, when the engine is stopped, the person attending lifts it up by the cord 12, 13, in order to discharge the steam.

A pipe of communication for steam, 10, 11, between the receptacle for feeding and the boiler, will be necessary; for while the boiler is heating to make the engine work (after standing some time) the feeding-cock being then shut, the water in this receptacle will boil before that in the boiler, and, possibly, by the sudden expansion of the steam upon boiling, might burst this vessel before the water could be evacuated at the little hole *c*, and yet, if so, being emptied of the water, might, by overheating the copper, break the soldered joints.

N.B. It is to be understood that in this, as in all other engines, the weight of the main pump-spear is so far to exceed the weight of the piston as to raise it, and overhaul all the gear, and that if not so, must be weighted till it will do it.

I have said nothing of the measures, for as every thing is drawn to the scale annexed, I did not choose to perplex the account therewith.

CALCULATION OF THE EFFECTS OF THIS ENGINE.

The diameter of the cylinder being 18 inches, the area in circular inches will be 324 inches, and allowing 7lb. to the inch, which such a cylinder will very well carry, we shall have 2268lbs. equal to the weight of the column of water to be lifted = 1 ton and 1 quarter of an hundred weight.

The pump working barrel being supposed of 7 inches diameter, the weight of a column of water of that size, and 1 foot high, is 16·7lbs. by which dividing 2268 lbs. to be raised, we have 135·9 feet for the height of the column = 22⅔ fathoms nearly; by a similar process, if the working barrel is 8 inches, the height of the column raised will be 17⅓ fathoms, and if of 9 inches, 13⅓ fathoms.

Such an engine may be expected to make ten strokes per minute, of 6 feet each, effectively; this, with the 7-inch bore, will produce 98¼ ale gallons per minute, that is, 113 hogsheads wine measure per hour; the 8-inch bore will produce 128¼ ale gallons per minute, that is, 148 hogsheads per hour; and the 9-inch bore will produce 162½ gallons per minute, or 187 hogsheads per hour.

It has been found by experience, that a 2-feet cylinder can be worked by one bushel of Newcastle coals per hour; the present cylinder being but 18 inches, the capacities will be as 16 to 9; therefore, if a 2-feet cylinder takes 24 bushels per day, an 18-inch cylinder will take but 13½ bushels per day, according to the common application of fire; but I have reason to think an engine constructed like this will not require above 9.

It has also been found by experience, that a horse will raise about 250 hogsheads 10 feet high per hour; consequently only 30¼ hogsheads at 13⅓ fathoms = 82 feet; but 187 hogsheads raised to that height by the engine is more than six times the quantity raised by one horse, and, consequently, acts with more than the power of six horses at a time; but in order to keep up this force with horses, night and day, three sets will be required, and, consequently, this engine will be more than equivalent to eighteen horses.

WHITBY HARBOUR.

Yorkshire, To wit, At the assizes held at the castle of York, in and for the said county, on Saturday the 20th day of July, in the fifth year of the reign of our Sovereign Lord, George the Third, by the grace of God, now King of Great Britain, &c., and in the year of our Lord 1765, before the Honourable Sir HENRY GOULD, Knight, one of the Justices of his Majesty's Court of Common Pleas, and the Honourable Sir JOSEPH YATES, one of the Justices of our Lord the King, assigned to take the said assizes according to the statute.

CHOLMLEY, Esq. against HOWLETT and MATHEWS.

IT is ordered by the consent of the said parties, and their attorneys, that the last juror or jury impannelled and sworn in this cause be withdrawn from the said pannel, and by the like consent, it is ordered, that the plaintiff shall execute, and the defendants shall accept, a lease with proper covenants for repairs by the defendant, and all other usual covenants, of the plaintiff's mills and fishery, in the pleading of this cause, mentioned at a rent equal to the highest neat profits, to be computed on a mean of any three successive years to be named by the plaintiff, which shall appear to the satisfaction of FOUNTAIN WENTWORTH OSBALDESTON, of Hunmanby, SIMON BUTTERICK, of Thirsk, and JOHN GRIMSTON, of Kilnwick, Esqrs., or any two of them, to have been made at the premises by the plaintiff; and also to enter into such covenants for cleansing the harbour of Whitby from the alum shale, which hath come from the defendants' works, within such time and in such manner as JOHN SMEATON, Esq. and JOHN WOOLER shall think reasonable, and also for the security of the said harbour from future damage from the defendants' alum-works. The survey and award of the said JOHN SMEATON, Esq. and JOHN WOOLER to be made on or before the 7th day of November next, and at the joint expense of the said parties; and it is further ordered, that such security shall be given, and penalties provided for the performance of the aforesaid covenants, as the said FOUNTAIN WENTWORTH OSBALDESTON, SIMON BUTTERICK, and JOHN GRIMSTON, or two of them, shall think reasonable and sufficient, and that the lease to be made shall be executed on or before the 20th day of December next, and shall commence, together with the rent, at that time, for the term of 99 years.

And it is also ordered, that there shall be no costs on either side, and that the defendants shall consent, that the plaintiff's bill, now depending in the Court of Chancery, shall be dismissed without costs; and that all other proceedings or actions now depending between the said parties, either at law or in equity, touching the matter in question in this cause, shall cease, and that no writ of error shall be brought, and that no bill in equity shall be filed against the said FOUNTAIN WENTWORTH OSBALDESTON, SIMON BUTTERICK, JOHN GRIMSTON, JOHN SMEATON, and JOHN WOOLER, or any of them, for any thing done by them under or by virtue of this order; and that this order shall be made an order of his Majesty's High Court of Chancery, if the Lord High Chancellor shall so please.

By the Court.

To all to whom these presents shall come, JOHN SMEATON, of Austhorpe, in the county of York, Esq., and JOHN WOOLER, of Whitby, in the said county, Gent., send greeting. Whereas, by rule of court, made at the assizes held at the castle of York, in and for the county of York, on Saturday the 20th day of July, in the 5th

year of the reign of our Sovereign Lord, George the Third, by the grace of God, now King of Great Britain, and so forth, and in the year of our Lord 1765, before the Honourable Sir HENRY GOULD, Knight, one of the Justices of His Majesty's Court of Common Pleas, and the Honourable Sir JOSEPH YATES, Knight, one of the Justices of our Lord the King, assigned to hold pleas before the King himself, Justices of our said Lord the King, assigned to take the said assizes according to the statute &c. in a cause then and there depending between NATHANIEL CHOLMLEY, Esq., plaintiff, and SAMUEL HOWLETT and JOHN MATHEWS, Gents., defendants, it was ordered, by the consent of the said parties and their attorneys, that the last juror of the jury impannelled in the said cause should be withdrawn from the said pannel, and, by the like consent, it was ordered (among other things), that the said defendants should enter into such covenants for cleansing the harbour of Whitby from the alum shale, which had come from the defendants' works, within such time and in such manner as we, the said JOHN SMEATON and JOHN WOOLER, should think reasonable, and also for the security of the said harbour from future damage from the defendants' alum-works. The survey and award of us, the said JOHN SMEATON and JOHN WOOLER to be made on or before the 7th of November then next, as by the said rule of court, reference thereunto being had, may, amongst other things, fully appear. Now know ye, that we, the said JOHN SMEATON and JOHN WOOLER, having viewed, surveyed, and examined the said harbour of Whitby and the river Eske as far upwards as Ibrondale Beck, and the said beck as far as the alum-works of the said defendants, which are situate and lying contiguous to or near the said beck, and also the said alum-works, we find, that not only the harbour of Whitby above the bridge there, but the channel of the river Eske, as far upwards as the said Ibrondale Beck, is greatly obstructed with alum shale, and also that the channel of the said Ibrondale Beck is greatly obstructed, and, in some places, nearly filled up, by the alum shale therein; and that the alum shale being in the said harbour, river, and beck, as aforesaid, has all proceeded from the said alum-works of the defendants, and has been carried down into the said river and harbour, in the time of floods and freshes, from the said beck; and that the said harbour of Whitby above the bridge there is greatly damaged thereby; and we also find, that the manner in which the said alum-work is carried on is such as will occasion still greater damage to the said harbour than it has yet received, by reason of other great heaps of shale and rubbish, from time to time proceeding from the said works, must necessarily fall into the said beck, and by the waters passing through the same, in time of floods and freshes, be washed and carried down into the said river, and from thence, by the said waters, and the additional waters coming down the said river above the said beck, carried into the said harbour, and there scattered about in an irregular manner, to the great detriment thereof, and particularly by filling up and choking the channel of the said river, where ships of great burden lie or have usually lain between the bridge of Whitby and about 160 yards above a place called the Oil House, and which was formerly called the Stone Key.

We do, therefore, order, adjudge, determine, and award, that the said defendants and their or one of their heirs, executors, administrators, or assigns, or some of them, shall effectually cleanse the present channel of the said river Eske, running through that part of the said harbour of Whitby lying above the bridge therefrom, and remove and carry away all the alum shale that shall be found at the time or times of such cleansing lying in the said river or harbour, between the said bridge of Whitby to 160 yards above the south-east corner of the building or warehouse now commonly called the Oil House, and which was formerly called the Stone Key, and which shall be found above the surface of a plane regularly inclined so as to be 14

feet below the top of the uppermost aisler course of stone in the present south-east angle of the said Oil House as it now is, and 16 feet below the top of the uppermost aisler course of stone under the threshold of the door on the east side of the warehouse or storehouse belonging to Mr. PLUMMER, being situate contiguous or near to the west end of the said bridge; and also, that they shall take and carry away all such alum shale as at the time or times aforesaid shall be found lying on the sloping sides of the said channel.

And we do further order, determine, and award, that the said defendants and their or one of their heirs, executors, administrators, or assigns, or some of them, shall effectually make, do, and perform, or cause to be effectually made, done, and performed, all such cleansing of the said river and harbour as herein before ordered and awarded, on or before the 29th of September, which shall be in the year of our Lord 1766.

And we do further order, determine, and award, that the said defendants and their or one of their heirs, executors, administrators, or assigns, shall from time to time, after the said 29th of September, 1766, take away and remove, or cause to be taken away and removed, all such alum shale as shall be found above the level of the plane above specified, or lying upon the sloping sides of the said channel; which alum shale, we adjudge, must happen to be so found or lying so long as the said alum-works of the said defendants shall be carried on in the manner they are at present, and so long afterwards as any of the shale proceeding therefrom, and lying in the said beck and river above the harbour of Whitby, shall remain therein in a state capable of being removed by floods. And we do also further order, determine, and award, that all such alum shale as shall, on cleansing the said harbour aforesaid, be taken away, shall be by, or by the order, and at the cost and charges of the said defendants, their or some of their heirs, executors, administrators, or assigns, carried or removed and lodged above the high-water mark of spring-tides, and deposited and laid in such a manner as no part thereof may, at any future period of time, slide or fall down into the said harbour, or otherwise that it shall be carried directly to sea, and discharged there in not less than 14 fathom of water. And, lastly, we do order, adjudge, determine, and award, that the said defendants shall, within 40 days after the date of this our award, enter into and make, and duly execute, a deed of covenants between them and the said NATHANIEL CHOLMLEY, or his heirs, wherein and whereby the defendants shall, for themselves and each of them, and their and each of their heirs, executors, administrators, and assigns, and every of them, jointly and severally covenant, promise, and agree to and with the said NATHANIEL CHOLMLEY, and his heirs and assigns, that they the said defendants, or their or one of their heirs, executors, administrators, or assigns, or some of them, shall and will, from time to time, and at all times hereafter, at their own cost and charges, well and truly make, do, perform, and execute, or cause to be well and truly made, done, performed, and executed, all and every the act and acts, thing and things whatsoever, before by us ordered, directed, determined, and awarded to be by them, or any of them, made, done, executed, and performed, or cause to be made, done, executed, and performed, as fully and effectually, and at or within such time or times, and in such manner as herein before mentioned, and according to the true intent and meaning of this our award. In witness whereof we have hereunto set our hands and seals this 18th day of October, in the year of our Lord 1765.

Signed, sealed, published, and declared by the above-named JOHN SMEATON, as his final award and determination, in the presence of us.

Signed, sealed, published, and declared by the above-named JOHN WOOLER, as his final award and determination, in the presence of us.

MARKET WEIGHTON.

HAVING viewed the out-fall cloughs of Fursdyke and Hudlett, as well as the leading drains up to Hotham Carrs, and from thence the country between this and Market Weighton, it appears to me as follows:

1st. That the most flooded part of those levels is Hotham Carrs, and parts adjacent to Wholsea.

2d. That the general surface of the lands in those Carrs lies at least 7 or 8 feet above the floor of Hudlett Clough; and, therefore,

3d. That by sufficient drains the surface of the water might be reduced 5 or 6 feet in Hotham Carrs, opposite Wholsea, even as Fursdale and Hudlett Cloughs now stand; and, therefore,

4th. That all the drainages which come to Hotham Carrs, by way of Foulney or Black Dyke, &c. may be equally reduced and improved; and consequently,

5th. That all the adjacent country may by proper branch-drains be refitted in like manner, by running their waters proportionably lower than they can by the present drains.

6th. It appears that Hudlett Clough (which I look upon to be lower than that and Fursdyke) lies at least 3 feet above low-water mark, spring-tides; and, therefore,

7th. That by erecting a new clough of proper dimensions, the waters might be run off at least 3 feet lower than they can possibly be done by the present cloughs, though the drains leading thereto were perfect.

8th. That from Hotham Carrs the low grounds have a considerable rise towards Market Weighton; and, consequently, that

9th. The affair, so far as regards to the drainage of these levels, will be perfectly easy and well conditioned, and executed at a very moderate expense, in proportion to the extent and value of the lands to be benefited thereby.

10th. Respecting navigation, it is no ways incompatible with drainage; for provided the cuts are made at an average from 18 inches to 2 feet deeper, the drainage will remain equally good, as if no navigation.

11th. A navigation may be made any where by means of locks, where there is water to supply them.

12th. Several locks will be required between the Humber and Market Weighton, besides the sea-lock; I apprehend, at least, 4.

13th. I am of opinion, that the brooks formed from the springs of Saneton and Houghton, which form Beal's Beck, the springs at Godmanham, which form Weighton's Beck, and those of Londebrough, forming Shipton Beck, when united, as they may easily be near Weighton, are amply sufficient for supplying the navigation-locks thither in the driest season: and I am inclined to think the two former becks will be sufficient, exclusive of the latter; but of this I cannot be certain, unless I saw the currents of those becks in the driest seasons.

14th. I apprehend it will be equally evident from the same principles that a navigation is practicable through the levels towards Pocklington, as I am informed the supply of water that way is at least equal, if not better; but as I suppose Pocklington lies in a higher situation than Weighton, a greater number of locks will be needful on that account.

15th. It is not possible to ascertain any thing respecting the cost of drainage or navigation towards either the towns of Weighton or Pocklington, without an actual survey of the principal drains, with a sketch of the adjacent country, as also an

accurate level taken from the low water mark at the Humber, distinguishing the heights of the relative surfaces of the water and lands up to the respective points where the navigation or drainage is supposed to terminate.

November 29, 1765. J. SMEATON.

A NEW BUCKET.

Description of a new Bucket for Fire-Engines.

N.B. The same things are marked with the same Letters, both in the Plans and Section.

Fig. 1st. A A is a ring of brass about $\frac{3}{4}$ of an inch think, to be turned upon the edge so as to fit the working barrel as near as possible, but not to stick in any part; but it will not be a fault if not more than $\frac{1}{16}$ of an inch less than the barrel: this being prepared, all the rest is made from it.

Fig. 2d. B B is a ring of forged iron, about 1 inch thick, and turned or filed round upon the edge, so as to be about $\frac{5}{8}$ of an inch less in diameter than the brass ring; this ring must be pierced with 4 oblong holes or mortices, C C C C, of 1 inch long and $\frac{1}{4}$ inch wide, and 8 round holes, *a a*, &c. which are to be tapped so as to take an $\frac{1}{2}$-inch screw. This ring is also furnished with a bridge or bar D D, which may either be made of one piece with the ring, as represented at the end *d*, or let in with a dovetail, and rivetted, as represented at the end *e*, either way, as the smith can best do it, so as to make all level on the upper side. The bridge is also furnished with 3 round holes of the same size, and tapped as the former.

Fig 3d and 4th. By means of the 4 square holes, the iron ring is to be fastened to the end of the spear rod, whose bottom part is to be divided into 4 branches, two of which, E E, are shewn in the upright section, fig. 4, and the horizontal sections thereof, fig. 3, supposed to be cut off a little above the ring, are marked with the same letters; the dotted lines distinguish the mortices, as in fig. 2d, and what lays without shews the shoulders, against which the upper side of the ring is brought square, and rivetted on the under side, by means of the tapt holes in the iron ring, and the plain holes in the brass ring, which are to be made answerable to each other; the 2 rings are to be screwed together by 8 screws, such as represented *f f*, &c. and betwixt the rings is to be screwed the leather *g g g*, &c. turned up round the iron ring like a dish, the skin or hair side being next the iron ring, and the opposite or flesh side next the barrel, the middle part of the leather being cut out answerable to the inside of the rings.

H H are the valves which are to be screwed down upon the bridge by 3 screws *i i i*, which confine down the rider K K, which is to be somewhat sloped and rounded toward the under side, to give more room for the leather of the valves to bend in the joints. I I are the upper plates upon the valves, and *m m* the under, which ought to be thin, to prevent stopping the water.

N.B. Small screw bolts with thin flat heads lying underneath, will be preferable to rivets for the valves, as the leather may be more easily shifted.

L, the shank, where the 4 arms are joined into one, by which it must be united to the take off joint.

OBSERVATIONS TO BE REGARDED IN MAKING THE ABOVE.

1st. The brass ring had best be cast without holes, that when the holes in the iron ring are tapped, the brass may be marked off from it, drilled, and opened answerable to the iron.

2d. The iron ring had better not be edged till the two rings are screwed together, by which means the border may be reduced to a breadth all round.

3d. The square mortices must be chamfered or opened on the under side, in order to receive a firm rivet when filed flat, and particularly end-ways; for this purpose the mortice should be at least $\frac{3}{8}$ longer and $\frac{3}{16}$ wider below than above, and the slope to reach $\frac{3}{8}$ upwards at the ends, and about $\frac{5}{16}$ at the sides.

4th. Particular care should be taken, that the tenons of those mortices at the end of the branches should be sound and tough iron, but not the softest, and that they may be rivetted with a hammer as heavy as a common hand hammer, that the metal may spread as well within as without.

5th. The tenons of the branches, I believe, had best be formed angle-wise upon 4 square bars, for then they will be in right position, when laid flat together, in order to be welded into one.

6th. The leather dish is to be formed as follows. Prepare an iron hoop about $1\frac{1}{2}$ inch broad, as near as possible the size within of the barrel, but better lesser than bigger; prepare also a round plug of wood, the size of the iron ring, fig. 2d. but rather bigger than less; let the plug be turned truly round, of some close wood, and square at the end; let your leather be of the best bend, but not the thickest; those are best that are evenest of a thickness; cut out a circle of leather $2\frac{1}{2}$ inches more in diameter than the pump barrel, therefore for a nine inch barrel $11\frac{1}{2}$ inches. When the leather is well soaked in water, lay it upon the ring, with the hair side uppermost, set the plug upon it, and with a few blows of a beetle, the leather will be forced into the ring, and will turn up round the sides in the same manner it is to lie in the pump, and thereby form a border without a joint of about $1\frac{1}{4}$ inch broad. When it has stood a while, take it out, and put it upon the iron ring of the bucket, and with a round-faced hammer beat the leather a little down upon the ring opposite to the holes, by which means their places will be marked; cut them out with any proper sharp tool, but the best is a leather punch, which is made for the coach makers, big enough for this purpose. This done, screw it into its place, trim it to an equal breadth, and chamfer the edge towards the barrel, as represented in the section, and cut out the middle answerable to the rings. In this way several leathers may be prepared at once, provided those that are to be kept are put on round boards, or something to keep them from drying into a lesser diameter. As the wet dries out, keep supplying them with oil, either train oil or sweet oil, or any oil that is not of a drying nature, till the pores of the outward rim of the leather that works against the barrel be in a good measure saturated therewith, and let this be done for the first leather as well as the rest; when the bucket is lowered down into its place, it would be well to pour down about $\frac{1}{8}$ of a pint of oil round the sides of the barrel, by which means, when the engine makes a stroke, the inside of the barrel will become besmeared therewith; but oil in the bending joints of the valves is rather to be avoided.

N.B. If on cutting out the circle of leather from the hide it appears thicker on one side than the other, let it be shaved with a sharp knife, so as to be of an even thickness.

If a barrel is very smooth bored without ring-galls, I esteem the surface best that is left by the tool; but if otherwise, let it be rubbed with a fine grit-stone; none

better than the grindstone kind that is got on Gateshead Fell. After the barrel is bored or cleansed as above, let its inside surface be oiled over, which will prevent its immediate rusting; and if so preserved till used, will make a great difference in the first leather.

The tenons at the end of the branches, by which the whole column is to be suspended, will undoubtedly seem small and weak; but it is to be remembered, that the bucket I saw at Aller Dean hung by two parts of barely $\frac{5}{8}$ square each, that is 50 square eighths; whereas 4 parts of 1 inch by $\frac{1}{4}$ are equal to 64 square eighths. After all, a column of 27 fathom and 9 inches diameter weighs but two tons, so that each part has only 10 cwt. to carry; therefore, there is no doubt of their sufficiency, if good iron and well put together.

N.B. There is no objection to lengthening the mortices.

Austhorpe, 11th December, 1765. J. SMEATON.

THURLSTON MILLS.

The Report of John Smeaton, Engineer, touching the matter in dispute between Mr. Rich and Messrs. Waltons, concerning their Mills at Thurlston.

As no particular question has been formally stated to me in writing, I apprehend the matter in dispute to be reducible to the following, viz.

Whether Messrs. Waltons have done any thing, by the erection of their oil mill dam, which they have no right to do, and whereby Mr. Rich's corn mill may at certain times be affected, and stopped by back-water?

As it will save many words, I refer to a sketch of the river and premises in question, hereunto annexed.

The rule that I have constantly followed myself in regard to the placing intermediate dams, whether for the erection of mills or navigations, and the same rule I have found practised by the best engineers and millwrights, and which is found generally subsisting in ancient mills. In flat countries, where levels are scarce, and consequently tail or back-water most burdensome and annoying, is to build those dams so that each dam shall not pen into the wheel of the mill next above, when the water is in its ordinary summer's state.

This rule I apprehend to be founded upon the following reasons: that if the erection of a dam does not affect the mill above by tail-water, when water is the most scarce in dry seasons, as every mill that is well and properly constructed will clear itself of a considerable depth of tail-water when it has an increase of head and an unlimited quantity of water to draw upon the wheel; and as in freshes and floods, at the same time that they bring a quantity of tail-water upon the wheel, they also increase the head, and afford a superior quantity to be expended. This is looked upon to be the proper means and equivalent by which mills are to be cleared of back-water, as far as is consistent with the mutual enjoyment of those great benefits of nature, namely, falls of water; and that this alone is very sufficient, appears from hence, that, in common, mills will bear 2 feet of tail-water when there is an increase of head, and plenty of water to be drawn upon the wheel, without prejudice to their performance; but mills well constructed will bear 3 and even 4 feet and upwards of tail-water: I have seen an instance of 6 feet; and it is a common thing in level countries, where (as said before) tail-water is most annoying, to lay the wheels from 6 to 12 inches

below the water's level of the pond below, in order to increase the fall of water, and, if judiciously applied, is attended with good effect.

If the rules above laid down are not decisive betwixt man and man, I believe it will be difficult otherwise to draw the line; for while some may think 3 inches a sufficient clearance, others may think 3 feet too little; and a third may subject himself to an action at law, after having been at a great expense and upon the best advice, for having done something to interrupt the free passage of the water 30 feet perpendicular below another's works, for there is no limits to fix the extent of imaginary evils.

I suppose it is a rule in the law, that no man can possess his own property in any new manner, that may be detrimental to his neighbour; but then I suppose it is equally a rule, that no man can acquire an exclusive power over another's property, to prevent him from turning it to profit, in the same manner as the first had done before him. It would seem very strange and unreasonable, and also very detrimental to the public service (of which the benefit of mills and machines worked by water is so great as scarcely to be estimated), I say it would seem very strange, if I have an estate through which a river flows, to which no one has any control but myself, in which there is 10 feet fall, and I have an occasion for a mill as well as my neighbour, that I cannot pen up the water to the same height as it before entered my grounds, and let it go at the same level as it used to depart, because the miller above says, that by keeping up this body of water within my ground, the water does not get away from his mill so freely in time of floods and freshes as it used to do; and the miller below says, Sir, you shall not build a mill there, because I cannot have the water from the mill above I used to do, but will be intercepted by your dam. To the former I should answer, the water shall have the same passage into my estate as it always had, but I *absolutely deny*, that you have ever had any right or occupation of a fall within my land; it is true, I have not made use of it myself before, but as I always had it in my power to do so, as you have done before me, if my not doing it so long, has been an advantage to you, you ought to thank me for having it so long, and not to think of precluding me from making the same advantage of the fall within my land, as you have done in yours.

To the miller below I should answer, You shall have the water delivered to you at the same level as before, and in the same quantity, for I neither intend to bottle it up, nor divert it from you; but as I have the prior right of using the water passing my premises, this I shall do in the same manner as you will do after me.

Thus much by way of explanation of those principles and maxims that, in my opinion, either are, or ought to be, the medium by which disputes of this kind ought to be adjusted. If they are true and valid, as they appear to me to be, there is not the least foundation for a complaint from Mr. RICH on account of Messrs. WALTONS' oil-mill dam; for it appears to be below the floor of Mr. RICH's mill-race no less than 1 foot 4 inches, and 10 inches below the bottom of the wheel, in the whole 2 feet 2 inches' fall in the compass of less than 100 yards from the wheel complained of to be put in back-water by the said dam: on the contrary, had Mr. WALTON penned considerably higher than he has done, he would not, in my opinion, have infringed upon the true rules of mill-building, especially in such a country as this, where the river runs so rapid as seldom to lay any mill in back-water above three hours together, and scarcely ever above six, not even the wheel complained of.

It is observable, that Mr. WALTON's dam pens dead water a considerable way up Mr. RICH's goit towards the letter P; but as this goit is without any floor laid, it may happen, that a flood coming and washing in gravel, &c. may raise the goit's bottom, while it is above Mr. WALTON's dam's water; or Mr. RICH, by clearing the

goit, may at pleasure sink it below; or the continual wearing of the mill's water may sink it below; as, therefore, the bottom of an unfloored goit is of an uncertain level, nothing conclusive can be deduced therefrom: thus much, however, it is certain, that no part of the oil-mill's dam's water reaches any part of Mr. RICH's goit where any floor or setting is.

How far, exactly, Mr. RICH's premises extend down the river, I know not; but, according to the rules already laid down, if Mr. WALTON has penned the water so as to raise its surface against Mr. RICH's freehold, he has done what, in my opinion, he cannot vindicate; it is, however, very manifest, that a considerable length of the tail of the jetty has, at some time or other, been taken off the river, as appears by the river's contracted breadth opposite thereto; and if, by consent of the Lord of the Manor, he has obtained a right of making this fence for the more effectually keeping open his water-course, he has not thereby deprived the Lord of the Manor of the use of such part of the perpendicular fall of water, as Mr. RICH has not by prescription or otherwise obtained the use of; for the sufferance of the Lord of the Manor, in letting a part of the natural fall of the river lay vacant, next below Mr. RICH's premises, must be considered in the same light as every other part of the unoccupied fall below.

I shall now proceed to a determination of this simple question, whether Messrs. WALTONS' oil-mill dam does or does not affect Mr. RICH's mill by back-water, in any degree whatsoever, as they now both stand? In order to this it must be remembered, that the bottom of Mr. RICH's mill-wheel lies 2 feet 2 inches above Mr. WALTON's dam water, that is, higher by 2 feet 2 inches than the water under the bridge when the oil mill-pond is full: the water, therefore, under the bridge must be risen 2 feet 2 inches before it comes upon a level with the bottom of Mr. RICH's mill-wheel; and I look upon it as a certainty, that Mr. RICH's mill would be going when the water was 18 inches higher than that, provided there were no impediments betwixt the bridge and mill, and the wheel itself properly constructed. Suppose, then, the water risen to that height under the bridge, that is, 3 feet 8 inches above the dam's height, in which case its mean depth under the bridge will be about 4 feet 8 inches upon 26 feet wide. Suppose, now, Mr. WALTON's dam away, and the water tumbling from the rock at E, in the manner it is said formerly to have done, still not above a certain quantity can be vented through the bridge at that given height, no more than can be vented over a dam at a given thickness, though unimpeded by any thing. According to my computation, the quantity that would be vented over the rock and through the bridge at 4 feet 8 inches deep (supposing the dam away), would be vented over the dam, which is 84 feet, in length, upon the crown, at a depth of 2 feet $1\frac{1}{2}$ inch, or thereabouts. Hence it appears, that in this state of the river there will be a fall from the bridge into the mill-pond of $18\frac{1}{2}$ inches, at which difference the bridge and rocks will vent the same water as if the dam was away. This may appear somewhat paradoxical to those unacquainted with these matters; but it is well known, that a stream of water issuing from a sluice, or opening, will run the same quantity so long as it clears its tail, as if unaffected by tail-water. At this height the balance is struck; and if, at this height, Mr. RICH's mill is not going, it must be owing to some impediments between the bridge and the mill, or to something wrong in the construction of the mill itself; at all greater heights the effect of the dam upon the water above is less, at all lesser heights it is greater; but if Mr. RICH's mill ought to go at the height above mentioned, it ought to go at all lesser heights, and if it will not go at lesser heights, it is very plain there is some obstruction between the mill and the bridge.

That there are, in fact, some obstructions, appear manifest from what JONATHAN LOCKWOOD, the millwright, alleged, that is, that Mr. RICH's mill was in back-water before the gravel bed in the oil-mill dam was covered; if so, since no part of the gravel bed was above 9 or, at most, 10 inches above the dam's water when full, it will appear, that Mr. RICH's mill is in back-water, when the surface of the water in the oil-mill dam (below the rocks) is 1 foot 4 inches below the bottom of Mr. RICH's mill-wheel: hence it appears, that very great obstructions are interposed betwixt the rocks and Mr. RICH's mill-wheel. Nor, indeed, does it need the evidence of Mr. LOCKWOOD to confirm this, the evidence arising from the things themselves being to me more strong, than that of any man living; for as soon as I set eyes upon Mr. RICH's mill tail goit, which is some distance below the covered part, not above 4½ feet wide, and seems still less where covered; when I observed, that both wheels delivered into the same goit, and the breast wheel in a very bad angle, as represented in the sketch, so that the breast mill stream must greatly obstruct the other; add to this, that instead of two small wheels of about 20 inches wide each, Mr. RICH has built one wheel of 5 feet wide, said to be able to drive three pair of stones at once, it is evident, that the superior quantity of water necessary for this purpose, and the additional quantity necessary to be laid on after the tail-water begins to touch the wheel; this again, added to the additional quantity also necessary on the same account to be drawn on the breast wheel, and this all crammed together into the same narrow goit that subsisted before the improvement: I say all this considered, it is very evident, that Mr. RICH's mill must be choked with water for want of sufficient vent. But this is not all; for as the jetty or fence that divides the tail of the goit from the river, as it narrows the river from about 30 feet, which is about the general width, to 21 feet, this will cause the water to swell, at least, a foot in the contracted part of the river alongside the jetty, when the river is 3 feet 8 inches at the bridge above dam's height; and as the jetty itself, for about 60 feet above the tail, is not at a medium much more than 3 feet above the dam's water, it follows, that before the water will rise to the height aforesaid, it will flow freely over the jetty for almost 100 feet upwards into the goit, and thereby fill the goit to nearly the same height as the water in the river abreast of the jetty, which, added to the obstructions before mentioned, must necessarily lay fast the overshot wheel, long before the water rises to the height under the bridge above specified, according to JONATHAN LOCKWOOD's observation.

From what is above laid down, it appears that when the water rises 3 feet 8 inches perpendicular at the bridge above the dam, that then the dam has no obstruction, because the dam will then vent the water as fast as it could have been vented through the bridge and over the rocks if no dam was there: but this supposes a free passage for the water between the rocks and the dam. How far the gravel bed at this height of the river acts as an obstruction (the water being at that time not less than 79 feet wide across the gravel bed) is not easy to say, without seeing the river in that state, the obstruction arising from the gravel bed not being subject to computation on account of the irregularity of its figure; however, as it must add something, especially at lesser heights, I would advise Messrs. WALTONS, for the sake of peace and good neighbourhood (provided Mr. RICH will be contented therewith) to oblige themselves, on or before Michaelmas Day annually, so long as their dam shall remain where it now is, to remove all such gravel as shall be found in their mill-pond below the rocks, and within the straight line from the south end of their dam, to the south side of the river where the rocks are, as shewn in the sketch *r s*, and to clear the same so that every part may be at least 8 inches below the top of

their dam-boards, and to lay the matter thence taken in such manner as not to be subject to get in the same place again. On the other hand, as it does not appear to me that Messrs. WALTONS have done any thing but what they may justify; and further, that on the strictest examination it does not appear that Mr. RICH's mills receive any prejudice from Messrs. WALTONS' works, but that the impediments found therein arise from the misconstruction of Mr. RICH's own works, I advise Mr. RICH (if Messrs. WALTONS will comply in removing the gravel bed as already specified) for the sake of peace and good neighbourhood, to be contented therewith, and drop all further prosecutions.

AUSTHORPE, December 14, 1765. J. SMEATON

HUBBERT'S MILL STREAM.

The Report of JOHN SMEATON, Engineer, concerning the power of HUBBERT'S Mill Stream to raise Water.

HAVING examined the capacities of the water-way at HUBBERT'S mill, situated upon a branch of the river Coln, near Drayton, in the county of Middlesex, I found them as follows, upon the 23d of February, 1766: at which time the currency of this branch of the river was said to be nearly the same as it always is when the mills above, upon the same branch, are at work, or their waste gates drawn, by which means the quantity of water going down this stream is regulated.

	Cube Feet per Min.
At Hubbert's Mill the discharge by a waste gate within the mill was	2166
By the water falling over the top of the waste gates without the mill	396
Total discharge in cube feet per minute	2562

	Feet	Inches.
The whole fall or difference at the mill was at this time	5	7

By the help of an hydraulic engine, properly constructed upon that head, and with the quantity of water above specified, the quantity of 356 feet cube thereof may be raised per minute to a perpendicular height of 20 feet above the level of the mill-pond, which quantity amounts to 2517 hogsheads per hour, accounting 52 ale gallons to the hogshead.

N.B. If the height is greater or less than 20 feet, the quantity will be inversely as the height.

It further appears on inspection, that the tail-water of HUBBERT'S mill (which stands upon a bye stream of the river Coln, as already mentioned), is nearly upon a level with the head-water of Lord UXBRIDGE'S mill below, which stands upon the main river; and that the tail-water of HUBBERT'S mill being conveyed by a meandering course, a full mile in length, falls into the main river below Lord UXBRIDGE'S mill: hence it is to be inferred, that in the tail-stream of HUBBERT'S mill there is a fall from that mill to the main river equal to the fall at Lord UXBRIDGE'S mill, which being measured the same day was 5 feet 6 inches, the greatest part of which perpendicular descent may be added to that of HUBBERT'S mill-fall, without affecting any other; that is, by straightening, widening, and deepening the said tail-water course from the main river to HUBBERT'S mill.

Now this being done, in a moderate degree, will add 4 feet to the fall of HUB-

BERT's mill, and still leave 18 inches for the declivity of the tail-stream; in which case, the quantity raised will be greater than before; that is, instead of 2517 hogsheads raised per hour, the quantity of 4138 hogsheads will be raised in the same time; but by a still greater enlargement of the tail-stream to about a 15-feet bottom, brought upon a dead level at the depth of $11\frac{1}{2}$ feet below HUBBERT's mill full head mark, it is practicable to add 5 feet to HUBBERT's mill-fall, leaving only $\frac{1}{8}$ a foot declivity in the tail-stream, in which case the quantity raised per hour will be 4482 hogsheads.

At other heights the quantities that may be raised are expressed in the following table.

It is further to be noted, that, according to the information of the millers, the river Coln in the driest seasons is not less than half of what it was upon the day above mentioned; so that HUBBERT's mill can then go at least half its time, and with the supply above specified; but by information that Mr. FORDYCE afterwards procured, they never are obliged to stop above 7 hours in 24.

The driest months, it seems, are August, September, and October, so that as the scarcest time for water is when there is the least occasion for it at London, and as we may reckon upon a constant supply during the winter and spring months, equal to what is above set forth, that is, during all such times as the town is fully inhabited, it follows that we may, in effect, compute upon the same supply throughout the year.

The whole quantity of water current in the river Coln, at the time above mentioned, was ascertained, by observing that two waste gates at Lord UXBRIDGE's mill being drawn, at that time discharged the currency of the main stream, the dimensions of the openings of those gates being taken, the quantity of water issuing was from thence computed; this, added to the quantity discharged by the bye stream at HUBBERT's mill, constitutes the whole quantity, amounting to 10,463 cube feet per minute, that is of 73,978 hogsheads per hour, produced by the river Coln: the proportionable quantity thereof proposed to be taken into the new canal, is set forth in the following table, according to the different quantities that a different fall at the mill, and height to which it is to be raised, will be produceable of, and is contained in the last column.

A TABLE,

Shewing the quantities of Water capable of being raised at HUBBERT's Mill, according to the different Heads or Falls, and according to different perpendicular Heights to which it is required to be raised.

Head or fall of water.		Perpendicular height to be raised above the mill-head.	Quantity raised per hour.			Proportionable quantity taken to that of the river Coln, Feb. 23, 1766.
Ft.	In.	Feet.	Cube feet.		Hogsheads of 52 ale gallons.	
5	7	20	356	=	2517	$\frac{1}{30}$ full
9	7	20	585,3	=	4138	$\frac{1}{18}$ full
10	7	20	634	=	4482	$\frac{1}{16}$ scarce
10	7	15	788,3	=	5573	$\frac{1}{13}$ scarce
10	7	10	1024,8	=	7246	$\frac{1}{10}$ scarce
10	7	$8\frac{1}{2}$	1125	=	7954	$\frac{1}{9}$ scarce

LONDON, March 10th, 1766. J. SMEATON.

P.S. Four hogsheads as above make a ton liquid.

CORN MILL AT WORKSOP.

The Report of JOHN SMEATON, *Engineer, concerning the Practicability of Erecting a Corn Mill, to be worked from the Farm Yard Pond, at Worksop Manor.*

THE fall from the surface of the farm-yard pond to the surface of the canal, in the New Menagerie, is 9 feet 6 inches, which is a sufficient fall for the erection of a mill; the principal difficulty, therefore, attending this affair, is to supply the said pond with water, sufficient to answer the intended purpose.

The quantity of water necessary depends upon the quantity of corn to be ground, which was stated to me at 10 loads per week, that is, 30 Winchester bushels.

The quantity of water necessary to grind one bushel of wheat into flour, will grind five quarters of malt, so that supposing 10 quarters of malt to be brewed per week, the quantity of water that is necessary to grind 32 bushels of wheat per week will despatch the whole business.

Now 3600 cube feet of water will, in this situation, be required to grind one bushel of wheat; and, therefore, 115,200 cube feet will be necessary to grind 32 bushels; and this quantity, at least, must be supplied to the farm-yard pond in a week.

	Cube Feet.
The overflowing of the pond at Steetly amount to, per week	40,019
A spring rising somewhat below, but which, together with Steetly overflowings, may be brought to the farm-yard pond	15,120
The pipes from Steetly, at 5 hogsheads per hour, which they are said to run, gives 1018 cube feet per day; $\frac{2}{3}$ of which I suppose will directly, or indirectly, come into the pond, amounting per week, to	4,751
The engine put in order, and the pipes repaired, as it now stands, will raise into the farm-yard pond per week	24,080
Total of the above, per week	83,970
The aggregate of the quantities before mentioned	83,970
The quantity required	115,200
Deficient..	31,230

The power 83,970 cube feet is sufficient for grinding $23\frac{1}{2}$ bushels, that is, besides grinding 10 quarters of malt, it will grind $21\frac{1}{2}$ bushels of wheat, or about 7 loads; but this is not supposed enough, though there is no allowance made for waste.

Coldwell Spring, having been carefully levelled, has been found to rise 6 feet nearly, higher than the surface of the farm-yard pond, when that surface was $9\frac{1}{2}$ feet above the canal of the New Menagerie.

The course for an aqueduct has also been traced out, and though it will be almost 2 miles in length, yet this spring may be thereby conducted, upon a sufficient declivity, to fall into the farm-yard pond.

Coldwell Spring being gauged in the month of March, 1766, then afforded 161,280 cube feet of water per week, a quantity capable of grinding near 45 bushels of wheat; so that here we shall have 46,080 cube feet of water per week to spare, or to allow for waste, and what the spring may afford less in dry seasons; but as it is said to be nearly the same in the driest seasons as when it was measured, we may safely reckon upon the whole quantity as above specified; nay, considerably more, because the defects will be more than made up, by taking in the brook that runs by the Coldwell Spring, which, at the time of measuring, was nearly equal to the spring, and in the driest season is said to run half as much; but if we reckon it only $\frac{1}{3}$ as much, viz. 53,760 cube feet per week, we shall then have a surplusage upon the whole of 99,840 feet per week, which is almost $\frac{1}{8}$ of the whole quantity found necessary.

Here, then, is a sufficient source of power not only effectually to answer the present purpose, but others also that may occur, and which in so large a family, may, in all probability, be very usefully applied.

As this spring is alone sufficient to answer the end, it would hardly seem a question which ought to be preferred; but as an aqueduct for Coldwell Spring will pass through rocky ground, in one part at the depth of 15 feet, and which, at a medium, will hold nearly $\frac{1}{8}$ of a mile, this, with some other difficulties, particularly the carrying it up the north lawn from the road, which being supposed a running sand, will be troublesome to dig, and will otherwise require arching; those impediments will induce a considerable extra expense; so that to overcome all probable difficulties, and to make the whole of proper dimensions and strength, will require the sum of 400*l.* to be expended upon it.

The deficiency of the former aggregates may, however, probably be made good by taking in the brook last mentioned: the particular observation was not made at the time, but, from the nature of the thing, it must be supposed that the water of this brook may be intercepted at such a level as to be conducted over the principal impediments that affect the Coldwell course, and, consequently, can be carried into the farm-yard pond, together with the water from Steetly, &c.; now, if we reckon as before, upon $\frac{1}{3}$ of the Coldwell quantity for this brook in dry seasons, we have 53,760 to be added to the former aggregate of 83,970, which, together, amount to 137,730 cube feet per week, which affords a surplusage of 12,530. This, however, is but barely sufficient to allow for waste, even if all the quantities held out in summer what they have been supposed from observations at the same time as those on Coldwell Spring were taken.

This aggregate scheme may probably be brought to bear for 150*l.*, if not 200*l.*, less than the Coldwell aquedect; yet, as a material part of the supply depends on the performance of the engine, this, if out of order, will render the mill defective also. The certainty of success, therefore, attending the Coldwell aqueduct, and the permanency of the benefits arising therefrom, as depending wholly on natural causes, being considered, as every other part of the work will be the same, whichever way supplied with water, it seems that the value of 150*l.*, or even 200*l.*, saved in the first erection will no ways counterbalance the superior degree of certainty attending the other scheme, as well as the further advantages that may probably be drawn from a superior supply of water.

A further and substantial argument for executing the Coldwell aqueduct is, that by means thereof the whole of the waters mentioned may be *united* at a small addition of charge; so that by this means, exclusive of the engine, and after deducting $\frac{1}{8}$ of the whole quantity for waste, we shall have remaining a neat natural power of 240,564 cube feet of water per week, a quantity capable of grinding 66$\frac{3}{4}$ bushels, that is, above 22 loads of corn, being more than double the power required; so that after serving very useful and valuable domestic purposes, in passing from the farm-yard pond to the canal of the New Menagerie, it will there furnish a fine supply of water for the cascade in falling from the upper canal to the lower.

I have mentioned 400*l.* as the probable expense of an aqueduct from Coldwell Spring to the farm-yard pond, which sum is drawn from an estimate made from such observations as have already been collected, and is intended to give the best idea of the expense that I can at present: and I also reckon that the mill-work, together with building the alterations that will be necessary in the farm-yard pond, and the drain that will be necessary for conveying the mill's water to the canal of the New Menagerie, will cost 400*l.* more. If, therefore, it is not thought worth while to

execute the scheme at the expense of 800*l.*, I would not advise to proceed upon it; but if so, then I shall be ready to make such further observations as the former have suggested, in order to make out a particular plan of the whole, from which a more exact computation may be drawn.

Newcastle, May 12, 1766. J. SMEATON.

SPURN POINT LIGHTS.

Description of the Machine for supporting the temporary Lights to be erected at the Spurn Point.

A B is the round pan, cage, or basket of iron, wherein the coal fire is made, to be 18 inches diameter, and 18 inches deep for the great light, and 16 by 16 for the lesser light, a little tapering towards the bottom.

C D is the mast for supporting the cage, at the height of 50 feet above the ground for the great light, and 35 feet above ditto for the lesser. The mast is hung upon an iron axis *E E* at the height of 22½ feet above the ground, and, consequently 27½ feet below the centre of the greater light, by means of which axis the fire-pan is brought down sufficiently near the ground to supply the same with fuel; the fire-pan turning upon an axis of its own, or swivel, so as to keep it upright in every position of the mast.

F is the stone, of sufficient weight with the butt end of the mast, to balance the fire-pan, coals, and iron-work at the other end, that it may turn freely, and in moderate weather be hauled down and up by hand of one man by means of two ropes, one fastened near the upper end, the other at the lower end of the mast, the stone to be hooped to prevent its splitting.

G G is a roller with winches, to which the ropes aforesaid being respectively applied with hooks for the more ready fastening to the staples in the roller, the mast will be managed in hauling down and up also by one man in the most stormy weather.

H H is a fixed piece of wood with a semicircular hollow, to which the lower end of the mast applies itself when in an upright position, and when necessary is retained therein by an half-circular keeper, plate, or clasp of iron.

a a the great axis of the mast, is supported upon two upright posts 22 feet 4 inches above ground, and 3 feet within ground, framed into ground-sills at the bottom, and each post braced in three directions; the feet of the braces to be framed into the ground-sills, and all the bearings supported by piles underneath, disposed as per plan.

I K are the two upright posts.

L M N are three braces belonging to the post *I*, and

O P Q are the braces belonging to the post *K*.

In order to keep the tops of the posts at a still more certain distance, the ends of the axis are to be finished each by a knob, to lay upon the outside of the bearing crutches or brasses, which will hinder the tops of the posts from flying out, and on the out ends of the knobs iron studs are to be driven into the top of the posts, which will keep them from coming together, the axis acting as a stretcher. The tops of the posts are to be hooped, the more effectually to fix the work thereon, and covered each with an iron plate to defend them from the hot cinders.

R is a pulley in order to set the rope at a proper distance for hauling down the mast by the windlass roll; this rope is to be annexed to about two yards of small chain fixed at the point *b*; such as is made for the smallest size of horse traces, will be strong enough.

S is an umbrella made of thin boards, to prevent coals, &c. from falling upon the person working at the roller, the pulley *R* is set at a distance in order that the rope for hauling down the mast may have the better purchase upon it when upright; where note, that this rope being fixed to the mast at *b*, when the pan is down, and the point *c* brought down to the point *e*, then the point *b* will come to the point *f*, and the tail of the mast will be at the point *g*, and the line *G g* will be the direction of the rope when it begins to act from the roller upon the tail of the mast, in order to hoist up the fire-pan and set it upright.

N.B. The balance of the whole is to be so adjusted, that when the pan is full of coals, the head of the mast will be heaviest, but when the fire is burnt low then the head of the mast shall be lightest.

The same letters refer to the same thing in all the figures.

The measures set down in figures refer to the greater light, but the measures will be given for the lesser light, by taking off the respective parts from the scale belonging to the lesser, which will give every thing in proportion to their respective heights.

Directions for the Smith.

It is to be observed that the fire-pan, with fork or crutch for supporting it, as well as all the iron-work at the mast head, is to be made as light as possible, consistent with the necessary degree of strength; $1\frac{1}{2}$-inch diameter will be sufficient for the two branches of the fork near their joining, and tapered to $1\frac{1}{4}$ near the holes for the axis on which the pan hangs, the rest in proportion; the whole to be made as short as possible between the top point of the wood of the mast and the axis, whereon the fire-pan hangs. It is also to be observed that the fire-pan axis projects 6 inches on a side beyond the ring, and that an iron strap be brought up from each side the bottom of the pan, and connected to the ends of the axis, as shewn in the front elevation, in order to prevent the axis from sagging by the heat of the fire. It must also be observed to make the round gudgeons of the fire-pan axis not above $\frac{7}{8}$ of an inch diameter in the round part, but the holes at least $1\frac{3}{8}$ or $1\frac{1}{2}$, and the gudgeons long enough that they may not jamb fast, or draw out by a little bending or sagging; one of the holes must also be made to open in order to change the pan occasionally, as repairs may require.

c c is the fire-pan's axis.

d d the two traps from the bottom.

EXPLANATORY REMARKS AND OBSERVATIONS

Upon the Designs for building the Lighthouses upon the Spurn Point, as approved of by the Honourable Corporation of Trinity House, Deptford Strond, London.

No. 1. *The General Plan.*

As the present variation of the compass at the Spurn Point is not exactly known, in case it should be found to differ from that supposed in this plan, viz. 20 degrees

westerly, the direction of the lighthouses in respect to one another are to be placed S.E. and N.W. by the compass, and the windows, &c. of the buildings to be placed according to the true meridian.

No. 2. The Section and Elevation of the Great Lighthouse.

The top of the stone setting or pitching of the foundation is herein supposed to be about 3 feet 6 inches below the general surface of the ground, from whence the height of 90 feet to the centre of the lanthorn is taken; but as it is intended that the said setting shall rest upon the bed of gravel or shingle underneath the upper stratum of sand, the depth of the foundation may be a little varied, according to the depth at which the gravel is found, so as to give the foundation a greater degree of solidity. The length of the piles may also be varied if they cannot be got down to the length specified, or in case they drive too easily to that depth.

In the section, *A* shews a pipe or passage-hole for the sacks of coals, from the coal-vault to the lanthorn, to be drawn up by the machine *B*, which also serves for drawing up the sacks of coals that are brought in carts from the waterside into the door *F*, by means of the small gibbet at *C*, from whence they are to be poured down into the vault by the trap-door *D*, when filled too high, to open the door *E*.

G is a pipe for bringing down the ashes.

N.B. The jambs of the doors are supposed in the estimate to be of stone.

No. 3. Section of the Lanthorn Pipe-Room.

The receptacle for the ashes, both bottom and sides, for 4½ feet in height, are supposed to be completely lined with plate iron of $\frac{1}{10}$ of an inch thick, to prevent the hot cinders and ashes from burning the wooden case; the door must be made as tight as possible.

Between the stone covers of the air tunnels *a a*, other stones are to be introduced, though not shewn on the outside, so as to complete a circle of stones, which are to be well crampt together, in order to form a chain course for the springing of the brick arch thereupon.

B B are large bellows, to serve when the wind does not blow strong enough.

C is a tunnel and ash-pipe, for the speedy conveying the ashes and cinders to the outside of the bottom of the house, when the receptacle is emptied, as it ought to be every day.

D, air-holes in each face of the lanthorns, to be stopped or unstopped with sliders, in order to prevent the lanthorn from smoking.

The hearth and floors of the lanthorn and balcony, together with the basement of the lanthorn, to be of stone; the roof and chimney to be of 4 inch Elland edge flags, properly mitred together; the balcony rails to be of iron.

No. 4. Shews the Plan of the Lanthorn Floor, and an Horizontal Section through the Air Pipes.

Where, in the plan, *A* is the passage or door-way up into the lanthorn, *B* the cover for the sack-hole.

At *a* is a hole for the rope to go down to the machine for hoisting the sacks, to be returned over pullies in the upper part of the lanthorn, so as to answer to the middle of the sack-hole.

b is a hole for a rope from the bellows, which, being returned in like manner over pullies, may go down into the pipe-room by the hole marked *c*, so as occasionally to

be blown there as well as in the lanthorn, in case that in summer time the lanthorn shall prove too hot.

In the section, *C* shews the place of the sack-hole.

d is a multiplying wheel and axle for working the bellows with ropes instead of a lever, which in this place would be inconvenient, especially when the person working them is in the lanthorn, as in general he is supposed to be.

N.B. The bellows are supposed to be made square, in the way of organ bellows, but with neat's leather, and nailed together.

e shews the flat of a slider, and *g* is the same in its proper position; each air-pipe to have one, in order to open any of them at pleasure, and regulate the force of the wind when too strong.

N.B. In order to give the wind its full force, two or three of them to the windward to be open, and all the rest closed, and when the bellows are used, to be all closed.

No. 5. Plan and upright of one of the Window-Frames for the Lanthorn.

Wherein the upright *A A* shews two of the upright pillars or stanchions to be of cast iron.

a a the sill, and *b b* the plating of strong iron bars, by which the pillars are connected; the window-frame is to be of wood, but strengthened by a bar of iron, laying within the middle horizontal bar, and screwed thereto, as represented in the plan at *c c c*.

No. 6. The Section and Elevation of the small Lighthouse.

As this lighthouse is to be constructed upon similar principles with that of the great one, and the difference of dimensions being assigned by this general design, it is presumed that a more particular description of the parts will be unnecessary, when reference is had to what precedes and succeeds relative to the great one.

No. 7. Design for one of the ten iron Stanchions that form the Windows, and support the Roof of the Lanthorn, drawn at large.

This, with reference to what is explained concerning No. 5. will be sufficiently clear from what is upon the face thereof.

No. 8. Plan and Section of the Fire-Cage and Hearth.

This is supposed to be sufficiently explained with what is upon the face thereof.

No. 9. Plan of the Foundation.

Upon the outward and inward circles of piles a kirb of wood is to be nailed down upon their heads, which are first to be cut level; but before the kirbs of wood are fixed down, the whole intermediate space between the piles is to be pitched or set with Elland edge setters, of 9 inches in depth, set edgeways, in the manner the streets are paved about Hallifax; those are to be well rammed down with a two-man rammer in the manner of a pavement, taking care that those setters that will be covered by the kirbs may be somewhat fuller than the pile heads, that the kirbs may take their bearings equally upon the setters as upon the piles: this done, the joints must be run full of grout, made of lime and sand made fluid with a proper quantity of water, which done, the brick-work must be carried on thereupon as shewn in No. 2.

No. 10. *Plan of the Vault or Basement Story.*

This is a plan of the vault at the top of the plinth or set-off above ground; the rest will sufficiently appear by reference to No. 2.

No. 11. *Smith's Shop Floor and Store Room Floor.*

Wherein the smith's shop floor *A* shews the great door, *D* the projecting landing-place, *E* the gibbet, *F* the machine or winch for hoisting the coals, *B* the hatchway for shooting the coals down into the vault, which being in the middle will be equally distributed, *C* the hatchway for the sacks to go up into the lanthorn, answerable to the sack-hole or pipe described No. 2. *H* shews the place of the ash-pipe.

In the plan of the store-room floor, *G* is the sack-hole, and *H* the ash-pipe, the east and west windows blank.

N.B. The doorway or hatchway had better be nearer the wall, as well in this as in the floors above.

No. 12. *The Dwelling-Room Floor and Chamber-Floor.*

After what has been remarked on No. 11, it is only necessary to observe that there being two opposite chimneys in the dwelling-room, they may be used the one or the other as best suits the wind; in the chamber-floor the north and west windows are supposed blank.

No. 13. *The upper Chamber-Floor and Pipe-Room Floor*

Will be sufficiently explained from what has been already remarked, the north and west windows in the upper chamber being supposed blank, as in the chamber below, the pipe-room windows all open.

J. SMEATON.

The foregoing explanatory observations were sent to London for the approbation of the Corporation of Trinity House, a copy of which was by them returned, in order to be returned to Mr. THOMPSON in their Common Seal, to which was subjoined the following.

TRINITY HOUSE, LONDON, March 21, 1767.

" These explanatory remarks and observations upon the design or plan of the two new lighthouses to be erected at the Spurn Point, the Master, Wardens, and Assistants of the Corporation of Trinity House of Deptford Strond, do hereby, under their Common Seal, approve of, and do appoint the same to be carried into execution, pursuant to the act of Parliament passed in the sixth year of his present Majesty's reign.

" By order of the said Corporation,

" CHARLES WILDBORE, Clerk."

ESTIMATE

Of the Expense of building Two Lighthouses, with Proper Conveniences, upon the Spurn Point, as designed by JOHN SMEATON, *Engineer, from the Orders and Directions of the Honourable Corporation of Trinity House, of Deptford Strond.*

ESTIMATE OF THE GREAT LIGHTHOUSE.

	£.	s.	d.	£.	s.	d.
To casting, piling, and setting the foundation, as per plan				123	10	0
To brick-work in the building				482	13	1
To stone-work in ditto				201	14	0
To carpenters' work in ditto				249	3	4
To iron-work in the lanthorn	100	14	4			
To ditto in the balcony rails	65	6	8			
To ditto in the fire-place, with 2 cages	30	8	0			
To ditto in the building	62	15	4			
Total of iron-work				259	4	4
To plumbers' work, covering the balcony floor with lead	56	19	3			
To ditto in cistern and pipes to bring rain water from the roof	15	6	0			
Total of plumbers' work				72	5	3
To glazing the windows of the rooms	5	0	0			
To ditto in the lanthorn	12	5	0			
Total of glaziers' work				17	5	0
Great lighthouse				1405	15	0
The great lighthouse, as per estimate				1405	15	0
The small lighthouse, estimated at $\frac{3}{4}$ of the expense of the great one				1054	6	0
The stone platform between the two houses				90	0	0
The brick wall round the greater lighthouse, 30 yards diameter, with carriage and small door, and capped with stone				118	12	0
Ditto round the small lighthouse, 27 yards diameter, but being more exposed, estimated at ditto				118	12	0
				2787	5	0
To the above allow for accidents, contingencies, and difficulty of situation, 10 per cent upon the whole				278	15	0
				3066	0	0

N.B. Nothing is allowed in the above estimate on account of supervisal.

LONDON, February 21, 1767. JOHN SMEATON.

This estimate was authenticated by the board, under their common seal, and with the following testimony:

"This Estimate of the expense of erecting two new lighthouses on the Spurn Point, the Master, Warden, and Assistants of the Corporation of Trinity House of Deptford Strond, do hereby, under their common seal, approve of, and do appoint the same to be carried into execution, pursuant to the act of Parliament passed in the sixth year of his present Majesty's reign.

"By order of the said Corporation,

TRINITY HOUSE, February 21, 1767. "CHARLES WILDBORE, Clerk."

(Duplicate. C. W.)

ADDITIONAL REMARKS AND OBSERVATIONS,

Touching the construction of the Lighthouses upon the Spurn Point, as approved of by the Honourable Corporation of Trinity House, Deptford Strond, London.

Design No. 1. *Being the General Plan.*

It is mentioned, that the lighthouses are to be placed at the distance of 300 yards centre and centre, and in a direction S.E. and N.W. by the compass, in respect to each other; to be joined by a platform of stone, the construction of which I propose to be as follows:

To be composed of Elland Edge natural-faced flags, 2 feet in breadth and 4 inches thick; to be supported by a pavement or setting of brick on the edge, and 3 bricks'-lengths wide, to be well beat down with a paviour's rammer, the ground being first levelled and consolidated by ramming: the hand-rail to be $3\frac{1}{2}$ inches square, supported by posts of $4\frac{1}{2}$ inches and 6 feet long, set in the ground, so that the rail may not be more than 3 feet above the surface of the flagging. This timber is supposed to be of Riga fir.

The circular brick wall round the great lighthouse, said to be 30 yards diameter, that is, out and out, I propose to found at the depth of 3 feet, or thereabouts, below the mean surface of the ground, but if at a less depth, a stratum of gravel can be found tolerably compact to found upon it. The bottom, when opened, to be consolidated by ramming, and the first ground course to be 3 bricks' length broad, set upon the edge, and driven down like a pavement; then two courses upon it to be laid flatways, as common, in mortar, of $2\frac{1}{2}$ bricks wide; then to be carried up of two bricks till a foot above the ground; then to be raised to 8 feet 8 inches high above ground, and to be capped with stone 4 inches thick: this, if the undertaker chooses, may be of Elland Edge flagging, with the natural faces, but hewn true to a joint and regular border; or with any other kind of stone, such as used about the lighthouses, that will bear the weather: the capping to project about 2 inches on each side, and to drip towards the outside, to be laid on with mortar made of lime from Barrow, in Leicestershire, or any other lime of equal quality for water-works. The body of the wall to be built with lime from Houghton, near Castleford, Yorkshire, or any other of equal quality.

The small lighthouse circular wall to be founded as the former, but the mortar courses on the 3 bricks' length on edge setting; to be raised $2\frac{1}{2}$ bricks thick to 1 foot above ground, and then 2 bricks to 8 feet 8 inches above ground, and covered with 4-inch capping like the former, without any projection on the outside; and about 2 inches within, but laid so as to drip outwards, the outside-brick breadth to be walled, and the capping to be laid on with Barrow lime, and the rest walled with Houghton, and both walls to be grouted or run with liquid mortar every four courses.

The area of these two courses between the lighthouses and the out-walls should be paved with good bowlers, so as to resist the wheels of carriages carrying coals. This article has not been particularly considered in my original estimate, otherwise than in the articles of contingences.

Design No. 2. *Being the Section and Elevation of the Great Lighthouse.*

The external and internal circle of piles in the foundations are, as drawn, intended to be 10 feet long, and 10 inches diameter at the heads, and the internal piling of 9 feet long, and 9 inches diameter at the heads; but both these dimensions to be varied according as the ground proves on trying it with piles: the piles here

supposed are of oak, elm, beech, or alder, but may be of Riga fir, or any other kind of red-wood fir of equal quality for duration under ground, in which case, if square, 9 inches will do for the kirbs, and 8 inches square for the internal piling, the length being supposed the same as before.

The thickness of that part of the shell of brick-work marked 2 feet, is supposed $3\frac{1}{2}$ bricks, and that marked 1 foot 7 inches of 2 bricks thick; the bricks in the north being made larger than those in the south, it was supposed they might probably in walling make those thicknesses specified, but at the same time it was not proposed to have bricks made on purpose, but to be walled with the common size of bricks usually made in that part of the country, but they should not be less than the statute thickness for London; and, N.B., wherever a difference in the dimensions of the bricks, the thicknesses assigned to the several parts cannot exactly tally; it is the outside measure which is to be preserved, unless particularly directed to the contrary. The sort of bricks proposed to be used is what in the north are called water-bricks, in contradistinction to stock-bricks, but those to be particularly hard and well burned.

It was proposed to build the whole with Houghton lime, or other good stone lime of equal quality; but I am of opinion, that, considering the exposure of the situation, it will answer a better purpose to have the outside bricks in breadth walled with Barrow lime, leaving the undertaker to make use of what lime he chooses for the internal parts of the wall, being stone lime good in its kind, and well tempered; and that it will be better to allow the undertaker whatever difference there may be in the value of both sorts together, if any, when used instead of Houghton lime for the whole, than that this precaution should be neglected. The whole of the inside to be walled fair, and to be grouted at every fourth course. The undertaker to be allowed to use, if he pleases, either sea water, or such as can be obtained by digging a well upon the spot, as he shall choose; and to prevent any damp in the dwelling-room, it will be proper to be stoothed, lathed, and plaistered (the plaister being made up with fresh water), which will be a far more effectual defence against damp, than any difference that can arise from the quality of the water in the out-walls, having found that good mortar binds as well with salt water as fresh.

N.B. This article of stoothing and plaistering was not considered in the original estimate.

In regard to the stone-work, all the parts that require large flat stones will be best supplied from Elland Edge, or from Cromwell Bottom quarries, which are of the same quality; but in regard to the stone-work for door-cases, window-sills, steps, the air-pipe mouths, and girdle-stones, to complete and cramp that course together, with the mutules and facia composing the balcony-floor and basement of the lantern, as there are a number of good quarries in the neighbourhood of Aire, Calder, and Dun, as well as at Sunderland, which afford the proper materials, the undertaker should have the choice of getting them where he can serve himself with most advantage, being obliged to furnish good strong stone, and such as will endure the weather.

Instead of lintels on the insides of the doors and windows, they are proposed to be arched with brick.

The timber everywhere to be made use of is supposed to be the best Riga fir, or other red-wood fir of equal quality, for the respective purposes, except where the sort of wood is particularly expressed to be of a different kind. The doors between room and room are proposed to be trap-doors, and the ascent between room and room to be strong step-ladders of equal width with the door-ways, the sides to be,

at least, 8 inches by $1\frac{1}{2}$, and the steps not to exceed 8 inches' rise, and the ladders not to stand steeper than an angle of 45 degrees, where the place will properly allow it.

The windows of the rooms to be of clean well-seasoned English oak; they are designed to be simply a frame, whose outside circumference is 3 inches by 2, and the inside bars of stuff $1\frac{1}{2}$ by 2 inches; they are to be fixed up against a check made by the projection of the outward bricks, and fastened by a pin, so that the whole frame may be taken out at pleasure, in order to air and ventilate the rooms, when occasion shall require, and the weather admit: there is a small error in the original drawings, in regard to the manner of forming the window-sole stones, wherein the check is represented on the outside, and that, for the sake of keeping out and venting the wet, ought to be within; and as this matter cannot be so easily described in words as to prevent all uncertainty, I have added a drawing, intituled No. 14, wherein the particulars are expressed more at large. The glazing of all the room windows supposed to be of common glass; the clear opening of all the windows, when the frames are out, is 2 feet wide by 2 feet 6 inches high, the pipe-room windows excepted, which are to be 2 feet wide by 2 feet high.

Their number will be as follows.

In the smith's shop	E. W. and N.	3	All the rest blanks, with arches and sole stones to preserve the regularity on the outside, and to be opened afterwards, if need should happen to require.
In the store-room	N. and S.	2	
In the dwelling-room....	E. W. N. and S.	4	
In the chamber	N. and S.	2	
In the upper chamber...	N. and S.	2	
In the pipe-room.....	E. W. N. S.	4	

Designs, Nos. 3 and 4. Being sections and plans of the lantern and pipe-room.

Upon No. 3 I observe, that the windows may, with more advantage, be placed two course of bricks higher, or nearer the pipe mouth-holes, that above the proposed lining with plate iron; of the receptacle for the arches, it will, for further security, be proper to line the whole inside of the wood-work, composing the upright tube, with double tin plate, and to extend the same the breadth of a tin plate within the air-pipes.

The stones mentioned to be laid between the pipe-mouth stones, marked *a a*, in order to form a chain course, are supposed to lie upon the same bed as the cap-stones of the air-holes, and to reach to the outside, wanting only one brick's breadth; that is, they will be 1 foot 6 inches up and down, and 1 foot 9 inches inside and out, at the extreme breadth: the whole of this course to be of stone of a firm quality, and double cramped upon the upper surface with cramps of 2 inches broad, $\frac{1}{2}$ an inch thick, and 14 inches long, and to be put in hot, and buried in a body of lead: the facia, in like manner, composing the balcony floor, to be cramped with a double set of cramps fixed in the same manner, the joints thereof to be filled, and very carefully pointed with cement made of equal parts of Barrow lime, and pozzolano or smiths' forge scales: the aperture or crown of the arch to be set round with an arched circle of stone of 9 inches thick, and the height of a brick's length.

The top of the balcony rails to be, at least, 3 feet 6 inches above the floor, and 3 feet high in the bars, which are to be of $1\frac{1}{4}$ inch thick, and 100 in number in the whole circle, and the upper and under circle connecting them to be 3 inches broad, and $\frac{5}{8}$ inch thick; this circular railing to be supported by 20 studs leaded into the facia, and turned with a crutch at the top, to take the lower circle of the railing, without any other fixing thereto than the weight of the railing.

The lower sill of the lantern-frame to be set in putty, made of white lead and

oil, the upper sill of ditto to be covered with a kirb of wood, bolted down, to be cut to a proper bevil for supporting the stone roof; this kirb to be oak; the chimney to be composed of five pieces, and to be hooped with two strong hoops round the whole, of 3 inches head, and $\frac{5}{8}$ thick.

N.B. It will be necessary to cut a small half-circular grove under the facia, to prevent the wet from following the under side to the wall. The door in the balcony from the lantern to be of oak.

Designs Nos. 5 and 7. The former being a plan and upright of one of the window-frames for the lantern, and the latter a design for one of the 10 cast-iron stanchions that form the windows, and support the roof of the lantern, drawn at large.

Upon which I have to remark, that the window-frames are supposed to be made of the best clean dry English oak, put together with white lead and oil, and glazed with the best crown glass, each frame to be fixed in place by 32 strong wood-screws, and by two small bolts, that take the cross bars; and that all the iron-work, together with the screws, bolts, &c., and window-frames, are to be put together with white lead and oil, the whole being first painted twice over when tried together, and afterwards two coats when fixed in place.

Design 6. Being a section and elevation of the small lighthouse.

Whatever has been or shall be observed regarding the great lighthouse, that will apply to the small one, is to be applied thereto, except what is particularly specified by the design or in writing to be otherwise.

The piles under this light-house are supposed to be of the same dimensions, and in number proportionable to the circumference of the circle of their respective bases, the stone setting between the piles to be of equal depth and solidity.

It now seems more eligible to make the room above the vault a store-room, and to put the two fire-places into the room above, in order to convert it into a dwelling-room, to be stoothed as the other.

The floors to be 12-inch beams, and common joists 4 by 5.

The height of the mutules are intended to be 6 inches, and the height of the facia 12 inches at the edge, and to rise $\frac{1}{3}$ an inch at the lantern, to be double cramped, as also the chain-course at the air-pipe holes, as in the great lighthouse.

The number of windows in the small lighthouse as follows.

The room above the vault	N.	1	The rest walled blank, with arches and sole stones, as in the great lighthouse.
The chamber and dwelling-room	E. W. N. S.	4	
The pipe-room	E. W. N. S.	4	
Open windows		9	

N.B. The windows of the rooms and pipe-room to be of the same dimensions as the great lighthouse.

This lighthouse is proposed to be furnished with bellows of a proportionable size to those of the great lighthouse; but I apprehend, the bellows in both lighthouses may be omitted till it be seen whether the fire may not have a sufficient draught in calm weather, by setting all the air-pipes open, without working the bellows; for, unless they are necessary, they may be cumbersome, and may at any time be added.

The sack-hole pipe is represented as broken off at top, not only in this elevation, but in that of the great lighthouse, the part of the arch wherewith it unites being that supposed to be removed from before the eye, but, in reality, those pipes are to be made to unite with the proper opening through the arch for the sack to pass through up into the lantern.

The balcony rails are, as per design, to be the same height, and the iron of the same thickness, as for the great lighthouse, but the number of bars to be only 80; the height of the lantern in the glass to be the same as the great lighthouse, and the cast-iron stanchions the same.

Design No. 8 is a plan and section of the fire-cage and hearth, upon which I have to remark, that it seems more eligible that the brick-work that supports it should be raised about a course higher, in order to bring the lower ring of the cage even with the top of the stone basement of the lantern; and, N.B., the spaces between the eight pillars that support it are to be closed with milled plate iron $\frac{1}{8}$ thick, one side being made to open with hinges and a latch like a door, in order to clear the grate.

Design No. 9 is the plan of the foundation; to which I shall add, that the kirbs, being 10 by 6, are to be of oak, elm, or beech; but that the internal piles are, as already mentioned, to be varied in number, size, and disposition, according as shall appear upon trial by driving after the ground is opened: the foundation here specified being such as appeared proper upon such trials as were made in presence of the gentlemen of Trinity-House, Deptford Strond, when I had the honour of attending them there.

Design No. 10 being a plan of the vault or basement story, there is nothing to add, but that the dotted lines upon the points E. W. N. and S. shew the places of four air-holes to ventilate and give light into the vault.

N.B. I apprehend it may be more eligible to make the entry-doors to open internally.

Design No. 11. is a plan of the smith's shop; floor to be flagged with natural-faced Elland Edge flags, well jointed and laid; the two openings *B C*, having a rebate cut round them, are to be covered with loose lids (with a ring in the middle) made of a double thickness of oak plank of $1\frac{1}{2}$ inch, clinched together; the middle hole, though marked 3 feet, need not be larger than the other, viz. 2 feet 6 inches.

The gibbet *E* to be of oak, and to have a rope of a proper length, with guide-pullies for hoisting sacks of coals out of the carts, separate from the rope for hoisting coals to the top of the house, each rope to remain reeved, and ready to be applied to the barrel of the machine as occasion shall require; the machine to be made with an iron wheel and pinion complete.*

In the store-room floor the door-way, upon the whole, may, in this as the rest, remain in the place shewn in the plan; the beams to be 14 inches square, the joists 4 by 8, and the joists on each side the door-way to be 6 by 8.

Design No. 12 contains plans of the dwelling-room and chamber-floors, wherein it is to be remarked, that the girders lie alternately cross of each other.

In the dwelling-room is proposed two fire-places, that either may be made use of as the wind blows; the funnels are to be carried up in the walls, and lastly carried to the outside, and to be terminated like a cup, by corbelling or oversetting the bricks near the top; those funnels to terminate at or about the height of the middle-chamber floor.

Before the chimneys are to be two hearth-stones of Elland Edge natural faced flags, of $2\frac{1}{2}$ feet broad at least, and 5 feet long; each fire-place to be furnished with a grate or range set in stones that will bear the fire; the girders of the dwelling-room floor to be 13 inches square, and those of the chamber 12 inches square; the joists the same as the store-room.

* The bellows and anvil are not supposed to be furnished by the undertaker.

Design No. 13 is added to shew the relative sizes and disposition of the floors, and seems to require no further directions than what is upon the face of it: the girders of the upper-chamber floor being 12 inches square, and those of the pipe-room 13 inches square; the common joists being 4 by 8, and the door-way joists 6 by 8, like all the other floors.

The iron-work for hanging the doors as follows:

The double doors for carriages to be 9 feet clear width in each of the circular walls, to be hung upon well-made loops and crooks, not less than 8lbs. loop and crook together; the crooks to be leaded into stone inlaid in the wall, and the loops to be fixed to the doors with small screw-bolts. These doors to be made with proper bars and fastenings to hold them open and keep them shut. The small doors in the circular wall, $2\frac{1}{2}$ feet clear width, answerable to the platform from house to house, to be hung with loops and crooks of 5lbs. per loop and crook, and leaded into stone with proportionable latches and bars. The vault doors to be hung upon the same loops and crooks as those specified for the double doors of the out-walls, and fixed in the same manner, with each two bars or bolts of 4lbs. each bar, and a lock to each door. The entry doors to have the same loops and crooks as specified for the small doors in the circular walls, with each a lock, bolt, and latch of proportionable strength. The crane doors and balcony doors to have loops and crooks the same as the out-wall small doors, with each a bolt of proportionable size. The trap-doors to the floors to be hung upon good HL hinges of at least 10, or T hinges of 13 inches, with one bolt of a proportionable size.

All the doors to be plain batten doors, except the two entry doors, which are supposed to be done with somewhat more neatness; all the out-doors to be of whole deal, and the trap-doors, on account of lightness, not less than $\frac{1}{8}$ thick when worked, all the doors and floors to be planed and shot clear of sap, and to be lathed, tongued, or rebated together.

The article of painting was not considered in the original estimate, otherwise than by the general article of contingences; but it is proposed, that all the outside wood and iron work be painted with at least two good coats, which has not been already specified to be done with more; all the sash-frames with white lead and oil, all the iron-work with white lead and oil made of a dark lead colour with lamp black, and the doors, &c. with good red priming.

In respect to the lead covering of the balcony floor (which was proposed to be done with lead of about 10lbs. to the foot) in case the joints are well cemented, as has been specified, I am of opinion, on reconsidering this article, that the lead may be omitted; and as the roof of the lantern and floor of the balcony will be greatly annoyed with soot and coal-dust, insomuch that it is probable but very little of good fresh water can be collected, it seems that the lead pipe and cistern may also be omitted, and in lieu thereof that the undertaker furnish each lighthouse with a good stone trough or cistern, to hold at least two hogsheads each, properly supported on brick-work, with a cover to each, for depositing such fresh water as shall be brought from the mainland; and also to cover the hips of the lantern roofs with lead; and as, in the above articles of lead-work to be omitted, there will be a deduction of 72*l.* 5*s.* 3*d.* in the original estimate upon the great lighthouse, and 54*l.* 3*s.* 11*d.* upon the smaller one, it may be reasonably expected that those sums, making together 126*l.* 9*s.* 2*d.*, will fully compensate every article of additional expense which was not fully considered in the first estimate, or has on this revisal been suggested.

I beg leave further to observe to this honourable corporation, if they can admit both the lighthouses to be somewhat altered from the places marked out in the plan No. 1, that is to go upon the same line about 80 yards more to the N.W., in order to bring the small lighthouse more out of the way of the seas in time of storms at high water, that it would be a means of preventing unforeseen expenses in the protecting the out-works of the small lighthouse from the effects of such insults; and this appeared to me the more desirable when I was upon the view of the temporary lights (in order to make an estimate thereof) as some derangements had happened to the platform and coal-yard near the small lighthouse by a storm happening at a great tide.

Austhorpe, May 9, 1770. J. SMEATON.

THE REPORT

Of John Smeaton, Engineer, concerning the state of the Lighthouses building at the Spurn Point, under direction of the Trinity House, Deptford Strond, London.

The beginning of December last I was at the Spurn Point, in order to view the state of the works carrying on there by Mr. Taylor, and found that the shell of the lesser lighthouse was erected, and the lantern completely framed, and set up, and ready for receiving the glass; all the naked floors in, and the hearth erected ready for receiving the grate; so that, exclusive of the balcony-rails, the glass, and inside finishing, this lighthouse may be considered as erected.

The foundation for the circular wall round this house has also been for some time laid, and brought even with the surface of the ground.

The great lighthouse was also then raised five courses of bricks above the second timber floor; both which floors were in place, and the arch of the coal-vault completed, as also the stone stairs up to the smith's-room floor.

The height of the greater lighthouse above its foundation was then 44 feet 6 inches, and near 40 feet above the ground, which is somewhat irregular.

The bricklayers were then at work, and as it is said there is seldom any frost at the Spurn Point, it is probable that the brick-work done in winter may become even more solid than what is done in summer. The brick-work of both houses is somewhat rough, but as Mr. Taylor seems very careful to have the courses properly grouted, or run with liquid mortar, I have no doubt of the firmness of the work, and which, at a very little distance, has all the effect upon the eye that can be expected.

On examining his stores upon the place, I found all the timber floors prepared, together with a large quantity of boards planed and tried up ready for the floors, doors, air communications, &c.; so that I apprehend, taking the work done and preparations upon the place, as they appeared upon my view the beginning of December last, in part of the whole, that 1000*l.* in addition would complete the two lighthouses according to the contract.

Mr. Taylor applied to me to have his extras settled, that is, the additional piles in the foundations, and depth of building, occasioned by the foundations being laid lower than the plan, and some other things that will be due to him; but I told him that as there might yet be others before he had done, it might be as well to settle all the extras together; to which he did not object.

Mr. Taylor has made a greater progress between the last and the former visita-

tion than in any former period, and, if not cramped for men or money, I should expect to see the lighthouses completed for use in the course of the present year.

The variation of the Point is become still more favourable to the present situation of the buildings than in my last representation.

Mr. Taylor remarked to me a new sand that the sea appeared to break upon at tow water, being due east from the lesser light by the true meridian, and at about a mile distance; this I remarked to some of the gentlemen of the Trinity House on my return to Hull, on supposition they would more circumstantially inform themselves, and acquaint this honourable board therewith.

London, 29th March, 1774. J. SMEATON.

Report upon the Lower Light at the Spurn Point, by John Smeaton, Engineer.

From a view of the works at Spurn Point, taken the 25th of April, 1776, it appears to me, that since my representation, by letter, of the 22d of January last, the beach has considerably increased, not only in breadth, but in height, and not only in the frontage of the low lighthouse and low temporary light, but for half a mile, at least, coastwise towards the north-east.

Since then a cargo of Hazlecliff stone has been deposited at the foot of the low lighthouse, upon the bricks reported to have been there deposited in the said letter, none of which appear to have been stirred from their place; but as the cover of Hazlecliff stone is not fully completed, I have now ordered a further quantity, in order to complete the same. A great part of both bricks and stone are buried in the beach, that a more favourable course of wind and tides have brought before the work as above mentioned; so that, from the above state, it appears, that as things have taken that favourable turn that was wished, and hoped for as very possible, the low lighthouse and low temporary light are not now in the imminent danger that they appeared in, in January last; and as there is now a greater appearance of probability that the low lighthouse may become and continue serviceable for some years to come, I am of opinion, that the best way to turn the work out of hand, and to give it the best chance of continuance, will be to rebuild that part of the circular wall that the sea has taken down, and, to give it a greater depth and dimensions than before, to make good the ground taken away in the courtyard; that will then again be inclosed solid with Hazlecliff stone, and also to deposit a quantity of Hazlecliff stone round the circumference of the new wall outside, in the same manner as is now done round the foot of the building; and, lastly, to construct some grynes of fascinery, or stake and rice work, upon the beach, on both sides the building, in order to catch and detain the beach, in a manner something like what is practised upon the coast of Sussex, in the frontage of Romney Marsh, &c. This is what, from circumstances turning out favourable for the present, appears to me to be now adviseable. Yet the opinion will remain valid that is particularly expressed in the 7th, 8th, 9th, and 11th paragraphs of the said letter of the 22d of January, and confirmed by the sketch of the gradual changes made in the Spurn Point since, and including the year 1766, remitted in my letter of the 24th of January, viz. that the whole coast for several miles being in a considerable state of waste to seaward, the sandy beach composing the Spurn Point must follow it, and, consequently, the ground

being taken away behind the lighthouse, it will be left an island, and, therefore, indefensible, but at much greater expense than that of building a new house, even of the same construction; but that, considering the fluctuating state of the coast to seaward, that it seems more advisable to exhibit the lower light, whenever the present one shall fail, by means of a machine lighthouse, built upon the same principle as the present temporary high light; and, by way of provision for the constant exhibition of the lights, for the benefit and safety of navigation, that, in the meantime, the present large temporary light machine (as soon as those lights are ordered to be struck) be removed into the line as near the low lighthouse as shall appear convenient. This is the general sense and meaning of the paragraphs in the letter above referred to, and which still appear to me equally necessary now as then appeared; but I now beg leave to add, that if the Honourable Board of Trinity House, Deptford Strond, shall think proper to order the rebuilding the circular wall, and the defences or outworks above mentioned, that it will then be impossible for the sea to render the lighthouse unserviceable so suddenly as not to give time to do some business. If it should be liked better, the large temporary light-machine may be taken down, repaired, marked ready for putting up again, and safely deposited under cover, ready to put up whenever, by the sea's destroying the out-works, it shall appear advisable and necessary; but yet, as the timber and iron-work thereof have already been exposed for several years to the weather, it is my opinion that they will last as long, when exposed in the same manner, as if put under cover.

Austhorpe, 30*th April*, 1776. J. SMEATON.

ESTIMATE

For rebuilding the part of the Wall of the Low Light at Spurn Point, that was taken away by the Sea, and defending the same, as per Report.

	£.	s.	d.
To thirteen rods of brickwork, at 10*l.*	130	0	0
To timber and piling under the foundations	35	0	0
To Hazlecliff stone, inside the wall and out, 360 tons, at 6*s.* 8*d.*	120	0	0
To clearing foundations	5	0	0
To gryne-work of fascinery	10	0	0
Neat estimate	300	0	0
To 10 per cent contingences upon the whole	30	0	0
	£. 330	0	0

ESTIMATE

For taking down, moving, and re-erecting the Great Temporary Light, and placing the same in line of the other two Lighthouses.

	£.	s.	d.
To taking down	5	0	0
Removing	5	0	0
Repairs that may be wanted	15	0	0
New foundation, so as to be movable	25	0	0
Re-erecting the same	10	0	0
Neat estimate	60	0	0
To 10 per cent contingences	6	0	0
	£. 66	0	0

Austhorpe, 30*th April*, 1776. J. SMEATON.

ESTIMATE

Of what I have further ordered as necessary to complete the Lighthouses at Spurn Point.

	£.	s.	d.
A copper funnel for the great lighthouse, to be fixed in the same manner as that of the low light, and of a proportionable size; this, after deducting the value of the present funnel, to be returned	18	0	0
To fixing, screws, bolts, &c.	5	10	0
New cast iron fire-hearths, possibly may come to about	5	0	0
Some partitioning in the small lighthouse pipe-room, in order to make it convenient to lodge in; an addition to the ash-pipe; and several small jobs that I saw necessary, and ordered when I was there last, about	6	10	0
Austhorpe, 22d January, 1777.	£. 35	0	0

J. SMEATON.

THE CONCLUSIVE REPORT

Of John Smeaton, Engineer, concerning the Spurn Lighthouses.

In consequence of Mr. Taylor's letter of the 30th of March last, acquainting me that every thing I had ordered, as well extra as contract work, was done, I visited the lighthouses at Spurn Point, upon the 7th of April, and finding that the capping of the detached circular wall of the lower light was completed, which for some months past had been the only thing wanted to the completion of his contract works, I gave him a certificate accordingly, of which I advised the Board by letter of the 20th of April; and also therein mentioned, that having staid the night of the 7th upon the Spurn, that the large copper funnel then fixed upon the great lighthouse completely answered the end, as the lesser one fixed upon the low light had done before, so that both lanterns would go through the whole night, without any necessity for cleaning during the night; and that both lights appear exceedingly brilliant, and the heat within the lanterns is proportionably less. These are, in fact, very great and essential improvements, both in regard to the light itself, and the advantage of keeping them, and, therefore, directly tending to keep the expense of maintenance as low as is consistent with the goodness of the light necessary to be exhibited, and which, as these lighthouses differ materially in construction from any before erected, are matters that could only be adjusted by trial and experience, but which being once brought to bear, will be a model or example for the erection of others. On examination, I found that the grates I had ordered for the new hearths being as much too small and narrow as the original ones were too large and wide, the light-keeper (being by trade a smith) had made one for the great light a medium between the two, which had answered, not only for the Stone coal, but for burning a mixture with the Sunderland coals, which, as the Board did not approve the disposal thereof, was become the more necessary; but the lesser light's grate being too narrow to burn the Sunderland coal, I thought proper to order another grate also for the lesser light, by means whereof, they said they could burn one-third of Sunderland with two-thirds of Stone coals; and, according to this rate of consumption, they had as many of the Stone coals as would last till Midsummer (of which I took care to apprise Mr. Corthine, the agent), and as many Sunderland coals as would last several years. Indeed the Sunderland coals are much in the way, as, by occupying the coal vaults,

the Stone coals have been obliged to be lodged in the yards, and receive much damage by being exposed to the rains and the frosts.

I observed that a good deal of gravel and beach had been laid on before the lesser light, and that no material variation had happened in the Point; in short, that things appeared in as tenable situation in every respect, as they had done twelve months before, when I advised the rebuilding the wall; and though, according to the accounts I have since received from Mr. TAYLOR, more beach is still laid on, and matters appear still more promising, yet, as in the great storm at N.E. that happened in February last, the whole of the Hazlecliff rubble was dispersed from the S.E. side of the wall for 60 feet running; and though much pains and care appear to have been taken by Mr. TAYLOR in collecting and replacing the same from time to time, yet the total stock laid outside the wall has been upon the whole considerably diminished; and as storms of this kind must be expected every winter, and there does not appear to me, though a temporary defence, any thing more likely to be effectual, or to afford a better chance of saving the building for a term of years, without going into expenses that cannot with any propriety be supported, as being greater than the expense of the building itself; I would, therefore, by all means recommend that for the present year 150 tons of Hazlecliff stone be got to the place ready to be applied as heretofore, that is, as it may be wanted; and as I have no doubt but that Mr. TAYLOR, while he remains an inhabitant of the Spurn Point, will not be wanting in his best endeavours to apply these stones to the best advantage for the defence of the buildings, I would advise the application thereof to be put under his management until Mr. CORTHINE can fall upon some more eligible person. Yet I must do Mr. TAYLOR the justice to say, that exclusive of such delay and disappointment as has risen from other persons, that in his own person I think him strictly honest and industrious; and I apprehend it is very possible that after they have got into a way of using the stones in a lesser body, and occasionally as they are wanted, that 100 tons annually may suffice, I mean till an extraordinary revolution happens, for in that case I do not apprehend that 1000 tons would be effectual.

I have already acquainted the board that the high light machine being erected upon the line, it can in two hours be lighted, so that no damage can happen to navigation by any failure of exhibiting proper lights; and as the machine is placed upon ground walls, by continuing these walls, and getting the machine upon rollers, it can with great ease be drawn further within land, whenever the wearing away of the coast shall require it.

AUSTHORPE, June 23, 1777. J. SMEATON.

P.S. The running out and shaping of the point itself was, when I was there last, much in the same state as it was in the year 1774.

THE REPORT

Of JOHN SMEATON, Engineer, upon the state and condition of the Low Lighthouse at Spurn Point, pointing out the most likely means of preserving the same at a moderate expense.

IN the year 1766, I attended a deputation of gentlemen of the Trinity Houses of Deptford Strond and of Hull, who were also attended by Capt. MITCHELL, who was supposed to know the coast the best of any body: he had previously set up marks

for the placing of the lighthouses, according to his own opinion; the line of direction was the same in which they now stand as to the points of the compass, but was more inland, that is, further from the Point than the line upon which the present buildings stand. It was then observed by the gentlemen, that the removal of the present light-house was on account of its being too far from the Point; and as the point appeared to be increasing, and going out further and further yearly, that the new light-houses might not soon become again necessary to be removed and rebuilt, it was desirable to have them as near the point as possible, as the probability was, that they would, by the increase of the Point, leave the houses more and more within the land. The only difficulty then seemed to be, whether the buildings could be so founded as to stand upright upon this great bed of sand, if built so much nearer the high water mark; upon which I said I could undertake to make foundations upon any part of the bed of sand, so as to enable the buildings to stand upright upon their bases, provided they were out of the way of the immediate stroke of the sea; and as it was universally allowed by all present that the land was increasing there in every direction, there could be little danger of a direct attack of the sea upon either building, and, therefore, the gentlemen ordered marks to be put down in the line on which they now stand, at the distance of 300 yards from each other, and which line was then only 115 yards distant from the extreme point at high water mark.

It was not till the year 1771 that the buildings were begun to be erected, when, on revisiting the Point, I found that it had so much increased in *length* that it projected at high water mark 280 yards further out than it did in the year 1766. The land had also increased on the side next the Humber, but had shewn a very apparent diminution to seaward. It had been determined to begin with the small lighthouse first, which being a less ponderous building, if any difficulty should arise in making a foundation, it might be a forewarning, and thereby furnish the means of conquering the difficulties that might attend the larger and more ponderous building.

Under these circumstances of the Point's having lengthened 280 yards in five years, it did not seem at all prudent to carry the line of the building further from the Point than had been directed, nor, on account of the diminution to seaward, to carry it further out; but finding room on the side next the Humber, I advised that they should be carried 80 yards further towards the Humber, upon the same line, than originally they had been proposed, and accordingly the foundation of the smaller lighthouse in question was laid 80 yards more inland than originally marked out, being there no less than 90 yards within land from high water-mark, which seemed to be a very ample allowance for the incroachment of the sea, that hitherto was not supposed to be any other than casual, and that, therefore, in all probability would increase again on that side as well as the rest: I, also, on this account ordered the foundation of the building to be furnished with a greater number of piles than originally intended. Having never been at the Spurn otherwise than by water, previous to the laying the foundation of the lesser light-house, it was not till that building was considerably advanced that I had an opportunity of remarking the progressive effect of the sea upon the coast, which my frequent journeys by land during the progress of the work gave me an opportunity of seeing. In the year 1772 the great lighthouse was founded, and though there appeared no diminution of the land on that side, yet, by way of precaution, I advised it to be set only 60 yards from its first intended position towards the Humber, instead of 80, which kept it 20 yards further from the Humber than according to the former position, and, also, by way of further security, I ordered this foundation to have an additional number of piles in like manner as the former. During the carrying on of these buildings, I

not only remarked that the sea was making gradual approaches toward the lesser lighthouse, but was wearing away the solid land of the coast for many miles to the north of the Spurn: however, its progress was not such as to denote any immediate destruction, till a great storm happening in January, 1776, that in two tides made such an incroachment upon the land as to take away the ground from under a part of the foundation of the circular wall, which occasioned one half of it to be beat down, and washed away the ground so as to lay bare a part of the piling upon which the main building stood; and had it not been for the precaution of the additional number of piles in its first founding, it most certainly had given way; however, there did not happen the least shrink.

On this alarming occasion, I defended the building with all the expedition that could be used, by a large quantity of Hazlecliff rubble-stone, forming a slope against the side of it to seaward, and in the advance of the spring the sea rather retreated than further wasted the ground. Seeing, therefore, from the gradual wasting of the whole coast, that nothing could be a permanent defence to this building but what would defend it as an island, after the sea had taken the land away round about it, and as this could not be done but at the expense of some thousand pounds, a much greater expense than what would erect a new building, I, therefore, advised, as the cheapest defence that could be made, so as to give it the best chance for a time, to rebuild the circular wall, founding it as deep as we were able at a moderate expense, and setting it upon piles, and surrounding the wall also with a slope of Hazlecliff stone, and, as a dernier resort, to erect the large temporary light machine in the line of the two buildings, 30 yards from the centre of the smaller lighthouse more inland, and to repair and fit up the same ready for lighting, at two hours' warning, so that in case any sudden or violent storm should render the house unfit for service, recourse could immediately be had to the machine light to continue the duty, all which was executed in the course of the following summer.

The beginning of the year 1777 there happened another violent storm at N.E. which the work sustained without any other derangement than that a part of the Hazlecliff stones laid on the outside of the wall was dispersed; therefore, after seeing the effects of this storm, I left it as my last advice, that "as storms of this kind must be expected every winter, there did not appear to me (though a temporary defence) any thing more likely to be effectual, or to afford a better chance of saving the building for a term of years (without going into expenses that cannot with any degree of propriety be supported, as being greater than the expenses of the building itself), than a proper application of Hazlecliff stones; I, therefore, recommended that for the present year (1777), 150 tons of Hazlecliff stones be got to the place ready to be applied as heretofore, that is, as it may be wanted, apprehending it is very possible that after they have got into the way of using the stones in a less body, and occasionally as they are wanted, that 100 tons annually might suffice, that is, till an extraordinary revolution happens, for in that case I do not apprehend that 1000 tons would be effectual."

At the same time I observed, that the high light machine being erected upon the line, it can in two hours be lighted, so that no damage can happen to the navigation by any failure of exhibiting proper lights; and as the machine is placed upon ground walls, by continuing these walls and getting the machine upon rollers, it can with great ease be drawn further within land, whenever the wearing away of the coast shall require it.

Austhorpe, 27th June, 1778. J. SMEATON.

THE REPORT

Of JOHN SMEATON, *Engineer, concerning the Situation of the Mills and Bleach-Field at Waltham Abbey in respect of Water.*

THE bleach-field is at present supplied with water, without diverting any water from the mills, as follows: the ditches are filled by the water from the barge river, which in time of flushes rises high enough to fill them, which flushes are constantly twice a-week in the driest seasons; the water for washing is the water that continually makes its way down the barge river, and in the driest seasons, when the mills keep the water below the top of Sir WILLIAM WAKE's turnpike, the leakage thereof is found sufficient for the purpose, as I am informed.

When the navigation is diverted from its present course, and this turnpike rebuilt, or something in lieu thereof, to hold up the head of water for the mills, it is apprehended that the turnpike may then be made so water-tight, and the leakage thereof so small as not to change the water of the present barge river with sufficient speed, to answer the purpose of washing the linens; nor can the ditches be then supplied with water as they now are for want of the flushes.

But the ditches may be supplied with water by a bore running continually out of the Waltham Abbey mill-pond, and the washing may be supplied by a bore running continually (or in the day time) from the new-constructed turnpike or flood-gate; this will, however, so far as it goes, be a subtraction from the mill's water, but yet may be done so as not to affect the powder-mills at all, and the Abbey mills very inconsiderably; on the other hand, it will be proved that both will be great gainers in point of water by the alteration.

Having, with the assistance of Mr. YEOMAN, Engineer, carefully veiwed, measured, and calculated the quantity of water discharged at Sir WILLIAM WAKE's turnpike in the driest seasons for passing the barges, it appears to amount to considerably more than 14* millions of cubic feet of water weekly, which, reduced to an average of the whole week, will amount to 1429½ cubic feet per minute, flowing continually, and which would supply a bore or round hole in a plank of 23½ inches diameter, whose centre is 2 feet below the surface of the water in the head from whence it is supplied; this is certainly a very great loss of water to the mills, and which must continue so long as the navigation remains in its present state, the greatest† part whereof will be saved to the mills jointly by the alteration.

Let us now examine what will answer the purposes of the bleach-field; having computed the quantities of water taken in for the supply of the ditches weekly, according to the information of the owner, I find it amounts to 140,000 cubic feet, that is at the rate of 14 cubic feet per minute nearly, which will be supplied by a hole of 2¾ inches diameter, running constantly, made in a brass or copper plate of ⅛ of an inch thick, and whose centre is placed 1 foot below the surface of Waltham Abbey mill-pond.

The supply of water for washing, supposing it done in the open river, as at present, would be considerable; but as the width of the stream, when barges cease to pass that way, may without detriment to the discharge of the flood water, be contracted at low water from 36 to 9 feet before the washing-stages, it will follow, that ¼ of the supply will produce the same velocity of the water in the river as at present, and, consequently, ¼ part of the leakage may supply it; but as the leakage of the

* The number comes out 14,408,875 cubic feet per week.

† The quantity expended by the new navigation will not be above $\frac{1}{3\frac{1}{2}}$ part of the present to do the business.

new flood-gates may not be 100th part of that at present, and greater or less according to the different states of repair they may be in, we will calculate what opening will supply, supposing no leakage at all.

The quantity necessary, when contracted as above, appears to be 135 cubic feet per minute, which will be discharged by a hole in a brass or copper plate of $7\frac{1}{8}$ inches diameter, the centre being placed at 2 feet below the surface of a full head.

This quantity, with the former for the ditches, makes 149 cubic feet per minute; but the quantity expended at the turnpike by the flushes being $1429\frac{1}{2}$ per minute, the quantity requisite for the bleach-field will be only betwixt $\frac{1}{9}$ and $\frac{1}{10}$ part of the water expended at the turnpike for navigation. Hence it appears, that upon the whole, at least eight parts in nine of the present water lost to the mill by the navigation will be saved, and yet the bleach-field amply served: hence, though the whole object of loss is trifling in proportion to the gain, yet there appears a method by which the waters gained may be minutely and justly divided; for if an additional bore be allowed the powder-mills, equivalent to the 7-inch bore at the turnpike, each property then will be equally benefited; for as the water of the bore taken from Waltham Abbey mill-head would otherwise be drawn at the mill, there ought to be no equivalent to the powder-mills on that account.

The account, therefore, will stand thus: To avoid fractions, I will suppose $\frac{1}{9}$ part of the savings to go to the bleach-field, which being wholly deducted from Waltham mill, a $4\frac{1}{2}$ part will go to the powder-mill as its full due, and a $3\frac{1}{2}$ part to Waltham mill.

The Waltham miller on this occasion, as usual, may not think he has his due, because he will not get in the very same proportion as his neighbour; but let us examine what he will get, and then his right to complain will be better judged of.

When I measured the mill's draught of water on Wednesday the 13th instant, I found the mill expending at the rate of 1087 cubic feet of water per minute, and, as the miller said, was capable with that water of grinding and finishing about 4 bushels of wheat per hour; and he further said, that in short water times he frequently had not the average of that water to go constant for the whole 24 hours; the quantity saved will, therefore, be as follows.

	Feet.
The average of water expended by the navigation per minute being $1429\frac{1}{2}$ cubic feet, and the half of this being supposed due to Sir WILLIAM WAKE, will be	$714\frac{3}{4}$
From this deduct the whole water for the bleach-field	149
Saved to the miller by the alteration, besides supplying the bleach-field	$565\frac{3}{4}$

Which appears to be more than $\frac{1}{2}$ of the water that he is in dry seasons possessed of, and sufficient to make an addition to his grinding of 2 bushels an hour constantly; so that instead of being injured, he will be greatly benefited.

But as some water will always leak at the turnpike, and as it is probable springs arise in the channel of the river, I apprehend a bore of 6 inches, at 2 feet under the top of the turnpike, will be a sufficient supply for the washing; and the equivalent will be most properly adjusted either by applying a new opening, or by widening the present one at the lowest orifice belonging to the powder mills. The size or widening of the present opening, if that method of adjustment is approved of, I shall be ready to compute.

LONDON, May 16, 1767. J. SMEATON.

N.B. The computation of 135 cubic feet for the bleach-field washing, is computed upon a supposition of the waters moving 10 feet per minute in a channel of 9 feet wide, and at an average of 18 inches deep.

REPORT

On Waltham Abbey Powder-mills respecting Navigation on the River Lea.

We, whose names are underwritten, having, the 27th of February, 1771, inspected the powder-mills of Waltham Abbey, belonging to Bouchier Walton, Esq; as also the several works of navigation from Rammy Mead Lock to King's Weir, upon the river Lea, in order to examine how far the said mills are, or may be, affected by the said navigation works, are of opinion as follows.

1st. That the said mills are considerably affected in their going when the water is held up by the new stop, called Waltham stop, so as to make more than 3 feet, which is esteemed navigable water, upon the threshold of the lower gates of Waltham Lock.

2d. That the said mills are affected, though in a less degree, even when there is 3 feet, and not more, of water over the lower gate threshold of Waltham Lock.

3d. We also observe, that the said mills are affected by the water-course leading from the said mills to the river, being not sufficiently clear of gravel, weeds, &c.

4th. It appears that the said mills become also affected by the passages for the water at Mr. Walton's weir, called the corning-engine weir, not being sufficiently ample, in consequence of the circumstance above mentioned.

Upon the foregoing matters we propose and recommend as follows.

1st. That a stone should be firmly put down in a conspicuous place near Waltham stop, to mark the height of 3 feet water upon the threshold of the lower gates of Waltham Lock, and that the keeper of the stop should have strict orders from the Commissioners of the navigation at all times to draw the gates of that stop, so far as to prevent the water rising there at any times above the said mark, unless requested for the sake of navigation to the said mills, or the town of Waltham Abbey, and unless in time of floods, when all the gates being drawn will not prevent it.

2d. After Mr. Walton has cleared the obstructions in the water-courses leading from his mills to the river, that what obstruction to the going of the mill still remains, be relieved by enlarging the water-way at the corning-engine weir, which we are of opinion will be done by an additional conduit or passage of 10 feet wide, its floor to be laid as low as the floor of the said weir, and to be furnished with a draw-gate or pointing doors to pen the water occasionally, so as to enable the barges to pass to the mills as at present; and as this enlargement can only become necessary by the water being pent at Waltham stop too high for the powder-mills, even at 3 feet above the lower gate sill of the said Waltham Lock, we are of opinion that this alteration should be made at the expense of the navigation.

Having also inspected Jones's turnpike, we found it not only out of repair, but materially defective, as the gate could not be shut down within some inches, and thereby a great quantity of water suffered to go down the old barge river, to the detriment of the mills aforesaid, as well as others dependant on the said head of water. Respecting which we are of opinion, that the said turnpike should be kept in good repair, on account of the said mills, and that the particular defect of not shutting down should be remedied as soon as possible.

We are informed, and believe it to be true, that the bargemen going downwards, after having passed the aqueduct lock next King's Weir, and taken the quantity of water necessary for passing them through the same, frequently draw a further quantity to keep them forward, by which means an unnecessary quantity of water is brought down the canal, whereby the said mills are not only detrimented by the loss of water,

but the navigation itself; for, besides impairing the banks of the canal, the current that helps barges going down obstructs those going up: it seems, therefore, necessary that proper orders should be given to the person having the care of the new stop of King's Weir, or otherwise to prevent these abuses.

London, March 27, 1771. J. SMEATON.

THE REPORT

Of John Smeaton, Engineer, upon the state of the River Lea Navigation, so far as the Mills abreast of Waltham Abbey Canal are affected thereby.

April 3, 1779, at the desire of Bouchier Walton, Esq., owner of the powder-mills at Waltham Abbey, I viewed the state and condition of the river Lea navigation, from and inclusive of the lock upon the cut next below Waltham Abbey cut or canal, up by the course of the said canal to King's Weir, and found the same as follows.

All the locks constructed without walled chambers, by which means not only much more water is necessarily expended at each lock for the passage of every vessel, but the passage of the vessels themselves are proportionably retarded by taking more time to fill and empty.

The head gates of all the locks within the above district were so considerably leaky, against which the water ought constantly to lay, except during the time of vessels passing, that I could not estimate the constant leakage at less than one of Mr. Walton's mill streams, which, in consequence, in all dry seasons, is lost amongst the three sets of mills abreast of this cut, viz. Enfield mills, Waltham Abbey powder-mills, and Waltham Abbey corn-mills; and which waste of water also retards the passage of the vessels; and which retardation, as well as waste of water, is also increased in case the tail gates are out of order, as I have reason to suppose they are,—the tail gates of the lock near the head of the cut next below Waltham Abbey cut, which was the only lock through which I saw any vessels pass, were very much so.

The waste of water above specified, though very material to the mills, is yet very trifling in proportion to the waste that will be occasioned, in case what I was informed of be really the practice, as I have reason to believe it is; viz. that vessels going down very frequently, if not always, after the lock is emptied, and the vessel is let down to the level of the lower canal, draw the cloughs or slakers of the head gates, and leave them both running a full bore of water, the same as while the lock is filling, in order to make a current down the cut to ease the horses, and help them forward upon their passage; and leave them running without returning to shut them, so that, in fact, they run till some other person has occasion to shut them, and during this time, which is indeterminate, a considerable portion of the whole river, when water is scarce, will pass this way, and be lost to the mills above mentioned; it being a rule, that what is lost at one lock, will also be lost to all the rest upon the same canal or head of water. This is a practice that ought by no means to be suffered, as, besides a damage of indeterminate magnitude to the mills, it is a very great and manifest detriment and hinderance to the navigation itself; because, whatever small benefit it may be to the ease of passage of vessels going down, it will be a greater hinderance to vessels going up; and when it happens, as must frequently be the case, that when any of the reaches of the canal or heads of water are drawn down from above, the vessels going up will be prevented navigating through the same, and must wait till those reaches are filled, by letting the water down from above in the canals,

or till supplied by the currency of the river Lea in the open river; which hinderances to the navigation itself very greatly surpass any advantage that can be drawn from the flashing of the vessels downwards.

These evils, therefore, are worthy of remedy merely for the facility of the navigation itself, but as relating to the mills, which can only have the surplusage, will be very destructive in dry seasons; and, I believe I may take upon me to say, very contrary to the idea wherewith the improvements were first framed before the last Act of Parliament was applied for.

For remedy whereof, as far as regards the first, viz. the wharfing up of the lock chambers, it is very difficult to be done now in a substantial manner with brick, as it will occasion the stoppage of the navigation for the time; but they may be wharfed up with piles, planks, and land-ties, keeping the navigation open; and where any of the locks so far fail as to need the water to be taken off, they may be wharfed with brick, as, to be substantial, they should have been done at first.

2d. As the mills are more immediately hurt by the leakages of the lock-gates, than the navigation, the mill-owners and lessees should have power to repair the leakage of the gates, and charge those repairs to the trustees of the navigation, in case they do not do it on competent notice given by the respective millers.

3d. The practice of flashing I do not see any adequate remedy to prevent, but by having a man or lock-keeper to attend each lock, by which the mills can be affected, with a proper hut to screen him from the weather; and two men will be necessary in case the navigation is unrestrained to all hours of the night; which men, as they become necessary by the misapplication of the bargemen of the proper mode and utensils of navigation, and being also for the benefit of the navigation, should, as it seems to me, be paid by the navigation, or a tax laid upon the bargemen; but being for the security of the millers, should be chosen or dismissed by the mill-owners or lessees immediately interested. Those men (it being made their duty so to do) will prevent much wear and tear in the use of the locks, and, by attending to keep the respective heads of water constantly full, with as little waste as possible, will thereby save much more time to the bargemen in the course of a voyage up and down, than they can possibly gain by any misapplication of the water.

I must also observe, that the banks in many places are too low and too weak, so that when the water goes over them it cuts them down in gullies, and this will necessarily, during the continuance thereof, occasion an extraordinary waste of water through the whole of such canals.

I also viewed the old turnpike, called Sir WILLIAM WAKE's turnpike, which, before the navigation was altered, was used as a pen of water, by means whereof, and through which, the navigation passed, but now is of no other use but to open in time of floods, and to be kept shut at all other times, to pen up water for the service of Waltham Abbey powder-mills and corn-mill, as heretofore, and which, for that reason, should be kept free from unnecessary leakage. When I saw it, by temporary repairs, it was sufficiently tight; but as it appeared to me, its main timbers and general state of repair and strength was so much impaired, that I should not be surprised if the first great flood of the Lea should take it away, in which case both the sets of mills at Waltham Abbey would be deprived of their water; it, therefore, seems, that though it is by law to be repaired at the navigation's expense, yet being no longer necessary thereto, it would be proper for the owners of these mills to take the rebuilding and future repairs upon themselves upon a moderate allowance from the navigation.

AUSTHORPE, April 17, 1779. J. SMEATON.

TO THE TRUSTEES OF THE RIVER LEA.

The Report of JOHN SMEATON, *Engineer, respecting the Alterations made at Sewardston Mill, so far as they concern the Quantity of Water taken from the River Lea, as, also, the Loss sustained by Sewardston Mill by an Alteration made at Enfield Lock, in the Year* 1781.

HAVING received no commission from the Trustees of the river Lea to determine any thing betwixt parties, I take the opportunity of reporting my opinion, as a professional man, upon the premises.

On Saturday, the 26th of October last, I carefully viewed and examined the mill of Sewardston, as, also, the present state and condition of the gauge sluice called Enfield lock, by which water is taken to Enfield mill.

Respecting Sewardston mill, and hearing what is alleged and agreed on both sides, in point of fact, is, that it has undergone no alteration except that of laying the floor of the corn-mill conduit lower, and the construction of the water-wheel correspondent thereto; that the sill or threshold over which the water issues, as well as the width of the gate, remains the same; this alteration, therefore, I am of opinion, will have the effect of grinding more corn with the same quantity of water, but not of requiring more water to grind the same quantity of corn, and to the height to which a miller may lift his gate or shuttle, I can conceive he can be under no restriction.

The mill being tried in my presence, with a full head of water, it appeared to despatch at the rate of upwards of 100 quarters of wheat per week.

I also took an admeasurement of the quantity of water used while working at the rate above mentioned.

I examined the present state of Enfield lock, being now restored to its former state before the alteration, and to the satisfaction of Mr. WHISLER; and comparing this with a model produced by Mr. WHISLER, and afterwards authenticated by Mr. NICHOLLS, as carefully made by him from measures taken at the time when the water was diverted into Enfield cut, in favour of the navigation in a greater proportion than formerly; I say, comparing this model with the state of the lock as I found it, it appears to me, that there would go into Enfield cut or mill river at that time considerably more water (over and above what ought to have gone through the proper gauge) than was taken by Sewardston mill to grind above 100 quarters per week, as above specified.

But as at the time of the complaint the waters ran so short that it was impossible to have kept up his mill-head to the height I saw it, and, therefore, could not have ground the same quantity of corn with the same quantity of water, Mr. WHISLER lays his account in his ability of only despatching 50 quarters per week, had the water been undisturbed; but reduced in the manner it appears to have been, he actually despatched but 20 quarters per week, thereby losing *bonâ fide* 30 quarters per week of what he might, and would have done, agreeable to what he has stated in his case of the 14th of February last, addressed to the Trustees of the river Lea.

As, therefore, it does not appear to me that Mr. WHISLER has made any alteration that enables him to take more water then he is entitled to; and as there does not appear any thing that shall check, so as to reduce the quantity of grinding lost per week, but rather that, from the above circumstances, Mr. WHISLER's statement of 30 quarters per week appears probable and well founded, I, therefore, see nothing that ought to hinder the admission of that quantity lost per week.

The whole length of time stated in Mr. WHISLER's case of 12 weeks and 5 days, I do not find controverted, which he reduces a fortnight on account of the time the gauges were shut down for cleansing the navigation; but as, during this time, he would have the whole water of the river Lea, he would be enabled to maintain a full head, notwithstanding the dryness of the season; and, therefore, in that fortnight could despatch above 200 quarters, that is, above 100 quarters more than the ordinary rate for a dry season, if the water had been divided betwixt Enfield mill and himself, as usual. This 100 quarters will, therefore, compensate the loss of 30 quarters per week for 3 weeks and 2 days, which, applied as a further set-off, will reduce the whole time that the loss of grinding continued, to 7 weeks and 3 days.

Respecting the rate at which he charges the loss of grinding, viz., 9*l.* per week upon 30 quarters, that is, at the rate of 6*s.* per quarter, or of 30*s.* per load, a price that I apprehend to be very far beyond the ordinary accustomed price of grinding in that district of country.

This is not to be doubted, that about the time of the hinderance mentioned, there never was known in man's memory so great and long continued a drought, and, therefore, all mills being short of water, there would be a great want of meal at the London market, and those who ground their own corn (as it is alleged Mr. WHISLER does, and could get it to market, would, doubtless, get extraordinary profits; but as on this head no evidence was laid before me, and it being a mere matter of traffic no ways determinable by rules of engineery, I must, of necessity, refer this point entirely to the Trustees, to satisfy themselves by such evidence of the fact at the time, as shall further occur, or be laid before them.

It has been observed to me, that the mouth of the mill-stream of Sewardston mill has been widened, contrary to a clause in the Act of Parliament, which allows that every part may be made wide enough for navigation to Sewardston mill, which widening, on the other hand, has been denied as to the mouth; I can, therefore, only say, it is of little consequence to the navigation of the river if wide enough at the mouth for a barge, and there is no restraint as to the depth. This restriction as to the mouth seems to have been introduced as a security to Enfield mill, that drawing from one common pond above Enfield lock, Sewardston mill should not get more than its share.

AUSTHORPE, November 12, 1782. J. SMEATON.

TO THE TRUSTEES OF THE RIVER LEA.

The Report of JOHN SMEATON, Engineer, respecting the Loss of grinding sustained at Tottenham Mills by the Leakage of the Lock Gates, from the Year 1778, *till April* 1781.

HAVING received no commission from the Trustees of the river Lea to determine any thing betwixt parties, I take the opportunity of reporting my opinion, as a professional man, upon the subject before me.

Being favoured by Mr. WYBURD with the state of his demand upon the Trustees of the river Lea, I find it consisting of various articles; but, so far as my judgment may be supposed to be of use upon the same, it must be in those articles containing a charge for loss of grinding at those mills during a term, from the year 1778, to the 2d of April, 1781, occasioned by a needless loss of water, arising from the disrepair of Tottenham lock during that time.

In this account, Mr. WYBURD particularly states the loss from the 30th of October, 1780, to the 2d of April, 1781, according to notice given to the Trustees of the loss he then supposed himself to be sustaining, viz. at the rate of 5*l.* 10*s.* per week.

The whole time intervening being 22 weeks, from this he deducts 7 weeks that he was fully supplied with water; there then remains 15 weeks, wherein water was lost in that period, which, charged as above, amounts to 82*l.* 10*s.*

No evidence was adduced to invalidate Mr. WYBURD's charge respecting the length of time as above; and it was very satisfactorily proved, that not only during that particular period, but for two years before, the lock-gates and slakers had been exceedingly leaky, and out of repair, and also had been misused, and great quantities of water expended to flash boats over a shoal, that had remained in the tail of the cut ever since its first being opened, till deepened 20 inches by Mr. GLYNN, in April, 1781.

Mr. WYBURD being desired to exhibit some testimony, whereby it might appear that his charge of 5*l.* 10*s.* per week was properly founded, Mr. BASS, his present mill-wright and foreman, alleged, that it was the general opinion of himself and millers, that the leakage of the lock-gates was as much as would drive one pair of stones. In further testimony, Mr. WYBURD produced a paper, said to be extracted from his books, at the desire of one of the Commissioners, by which, comparing what the mills had done for 12 weeks after the 20th of June, 1780, with what they did in the same period succeeding the 20th of June, 1781, after the lock had been repaired, he finds they did more by 30½ quarters per week in the latter year than the former, though it must be acknowledged the year 1781 was a dryer year than the year 1780.

He states, that in 12 summer weeks, 1780, they ground 1029 quarters; average per week....	85¼
Ditto, ...1781, ... 1395	116¼
Difference lost is Qrs.	30½

Upon which (as a fact) Mr. WYBURD reasons thus; if, when we ground 85 quarters per week, we lost 30, in grinding double that quantity, they must have a double loss; and in a triple quantity, a triple loss; and so on till they came to five times as much: so that, when their grinding amounts to 5 times 85, or 425 quarters per week, their loss amounts to 5 times 30, or 150 quarters.

The different grindings being, therefore, averaged thus:

1	85	lost	30
2	170		60
3	255		90
4	340		120
5 times	425		150

divide by 5) 450 (90 quarters per week will, therefore, be the average loss, amounting to 18 loads, which, at 7*s.* 3*d.* per load, amounts to 6*l.* 10*s.* 6*d.* per week.

Now, Mr. WYBURD, in reasoning upon the fact above stated, takes it for granted, that because a greater head of water which enables them to grind more corn, produces also more leakage, he supposes them proportionable, so that when they can grind five times as much corn, there is five times the leakage; but this is a very evident mistake, for if, with a 6 feet head, and suitable follow of water, they grind 425 quarters, the leakage through the same apertures, will only increase beyond what it would be at the ordinary summer's head of 4 feet 4 inches by ⅕ part of the

whole, so that if, upon grinding 85 quarters, they lose 30, upon 425 they will only lose 36, and the average loss will not exceed 33 quarters per week, that is, 6 loads 3 quarters.

Mr. WYBURD's mode of reasoning upon the subject, he seems himself apprehensive, if pursued to its extremity, was leading him into an incongruity, for, says he "when we grind 500 quarters per week, we do not mind the loss of water so much," that is, though, when grinding 425, they were reckoning themselves to lose, and ought to be paid for 150 quarters, amounting, at the above rate, to 10*l.* 17*s.* 6*d.* per week; yet, when they could do 75 quarters more, and, according to the same scale, would lose the grinding of 26½ quarters in addition, their loss would not then be worth minding.

That the loss of 33 quarters per week cannot be far from the truth, will appear by examining such collateral circumstances as have occurred.

According to the testimony of Messrs. BERNER and ROGERS, and also of JAMES FRENCH, who assisted them in examining the gates in question, by desire of the Trustees, (which they did the 24th of March, 1781,) the whole value of the several openings, according to their estimation, and the water discharged thereby, compared with the quantity requisite to grind a given quantity of corn (as deduced from an experiment made by myself upon this mill), could not amount to more than one quarter per day; but as the gates were doubtless then as carefully shut to as the circumstances of their disrepair would admit of, which could not in general be the case when handled by bargemen, nor would they, from the same circumstances of disrepair, always shut alike, I look upon this experiment as made in their extreme degree of tightness.

Again, it has been fully ascertained and agreed, that during this state of disrepair of the gates, that the lock would sometimes be 15 minutes in filling, and that it was frequently necessary to draw the head-gates open by the tracking horse, sometimes being done by simply drawing them open, and sometimes by the use of a block; and that, at such times, according to the opinion of WILLIAM BANNISTER, who preceded WILLIAM BASS as foreman at these mills, the water of the lock has not levelled by about 4 inches: he speaks of this, however, by estimation of the eye, not having ever actually measured it.

The tail-gates are also agreed to have been more leaky than the head-gates; had the tail-gates, therefore, been no more leaky than the head-gates, we may well suppose that 3 inches difference would have been sufficient to have brought as much water through the open slakers of the upper gates, as would have supplied their own leakage.

Now the quantity of water that would be vended by the two upper slakers upon a difference of 3 inches want of level, will be a given quantity, and will be equivalent to the leakage of the upper gates at these times, and this checked with the quantity of water used for grinding a given quantity of corn, as before-mentioned, will amount to the grinding of 9½ quarters per day; but as it was not necessary for the gates to have been always drawn open in this way, this appears to me to have been the extreme loss the other way; it is, therefore, fair to check the result obtained this way with what arises from the experiment of Messrs. BERNER and ROGERS, viz.

	Qrs. per Day.
When the gates were so leaky, as not to level within 3 inches, loss	9½
tight as per Messrs. BERNER and ROGERS, to lose but	1
Sum....	10½
Half will be the mean....	5¼

So that the average loss thus obtained will be $5\frac{1}{4}$ quarters per day, or $36\frac{3}{4}$ per week, which call 37.

	Quarters per week.
And again, if we check the average result obtained from Mr. WYBURD's experiment, viz.	33
Against the average result last collected	37
Sum....	70

Average of the averages, 35, that is 7 loads, which at Mr. WYBURD's prices, stated at 7*s.* 3*d.* per load, is 2*l.* 10*s.* 9*d.* per week, and which, in my estimation, will be so near the matter as not materially to injure either party.

£.2 10*s.* 9*d.* per week, then, for 15 weeks, is £.38 1*s.* 3*d.*

The idea of the millers, that they were losing as much water at the lock as would work a pair of stones, I must in this place observe I can have no reliance upon; had it passed through an orifice in one collected opening, they might have had some comparative notion, but, when cascaded in many different directions through the crevices of lock-gates, the best judge of these matters would be liable to be greatly deceived, and, from the magnitude of the appearance, judge it much more than it really was; and in this manner their idea of loss would be magnified from first to last.

Respecting, therefore, the charge of 200*l.* for two years preceding the 30th of October, 1780, no particular evidence was offered upon it, but the general one, that during all this period the lock-gates and slakers were greatly out of order; yet, since it appears that at three different times they were repaired, it is impossible to judge now what degree of loss Mr. WYBURD might suffer during that period; but if his own comparative idea of the matter be taken, viz. that while he was suffering 5*l.* 10*s.* per week in the period specified between the 30th of October, 1780, to the 2d of April, 1781, he was suffering at the rate of 100*l.* per annum for the two preceding years, then the yearly allowance must be reduced in the same proportion as the weekly.

	£.	*s.*	*d.*
That is, as 5*l.* 10*s.* is to 2*l.* 10*s.* 9*d.* so is 200*l.* to	92	5	5
Which, together with what was before ascertained	38	1	3
Total, for loss of water.....	130	6	8

With which I am convinced Mr. WYBURD will be fully recompensed for whatever loss he has in reality sustained.

I will only add, that I would have it understood, that I have supported Mr. WYBURD's claim of reparation of injury to an individual as much as I can with justice to the Trustees as a public body; at the same time adverting, that as in the nature of the use thereof, lock-gates cannot be made or kept perfectly tight for any length of time together, that a reasonable degree of leakage can be claimed by the Trustees as their right, by the same rule as they can take water for the lockage of the vessels, the mill estates upon this river being greatly benefited by the alteration of the mode of navigation from that of wears and flashes to that cistern-locks.

AUSTHORPE, November 12, 1782. J. SMEATON.

ST. IVE'S HARBOUR.

The Report of JOHN SMEATON, Engineer, concerning the Practicability of making the Harbour of St. Ive's safe for Ships in all Winds.

THE bay of St. Ive's lies about five leagues to the north-east of Cape Cornwall, and is the first harbour of any consequence after the entry of the north channel; it lies

nearly opposite to Mount's Bay, upon the entry of the British Channel; and, as there is a great scarcity of harbours on the north side of Cornwall, it becomes of consequence, from its situation, not only to ships trading through the north channel, but to such ships as homeward bound from long voyages, by hazy weather, or other accidents which often happen, get into the north channel, when they intended to make the south.

For these purposes the bay of St. Ive's is happily situated, and is sufficiently capacious, it being near four miles in width, and above two miles in depth, having, in general, and especially near the middle, full 10 fathoms at low water, with a clean bottom, being altogether a white sand, composed almost wholly of the small fragments of sea shells, so that, having very little of what is gritty in its composition, and the particles being rounded by the motion of the sea, is so soft and smooth as not to hurt the cables of such vessels as anchor therein; and as underneath the sand there appears to be a blue clay (it being frequently brought up upon the flukes of the anchors), is very good holding ground, the anchors being never known to drag when drawing towards the land, as the ground that way gently rises, and in the contrary direction, as the wind blows from the landward, the sea will necessarily be smooth, or, if driven out to sea can be of no ill consequence, as the passage is sufficiently open, with sea room enough.

At the north-west corner of the bay a bold rocky promontory, called the Island, is joined by a narrow neck to the main land, and projecting considerably forwards towards the east, forms a natural harbour on the north-west side of the bay, and defended from all winds except the north-easterly.

This interior bay forms the harbour of St. Ive's; and is, for the most part, left dry at low spring tides: but, on account of the fine soft sand before mentioned, that universally lines the bottom of the whole bay, affords a soft easy bed for ships to lie upon when left dry by the tides; and for such ships as have not occasion, cannot, or choose not to come upon ground, here is an excellent road where ships of any burden may ride, safe from all north-westerly, westerly, south-westerly, southerly, and south-easterly winds, in six and seven fathoms water, at low water spring tides, as appears by inspection of the draught of the harbour accompanying this report, where, at fig. 6, vessels may ride in six fathoms, the point of the island, called the Lamp Rock, being open with the Meran Point, and bearing N. by the compass (as all the bearings hereinafter mentioned were taken), the Meran Point distant scarce a quarter of a mile. At 7, there is, in like manner, seven fathoms, the lamp rock bearing N. by W.; and at fig. 9, nine fathoms, the lamp rock bearing N.N.W. $\frac{1}{2}$ W., from all which places the church tower bears nearly the same, viz. W. $\frac{1}{2}$ N., and at the island of Codrevy E. by N., distant about $3\frac{1}{2}$ miles; but vessels are by no means confined to these places, the water growing regularly and uniformly deeper towards the middle, where the general depth is ten fathoms, but these are the marks which ships bring up by, which use the road, in order to be as much sheltered as possible.

From the sketch of the bay, it appears that the rocks mentioned to be without Codrevy island, together with St. Agnes and Trevonse Point, stretch north as far as N.E. by E., so that it appears that the road does not lie quite open except from the north to N.E. by E.; these winds are not, however, dangerous on this coast, as they blow almost right out of the channel: yet it is desirable, for the sake of such vessels as come in here for shelter from the N.W. and westerly winds, or to prevent being driven back to Milford Haven* when outward bound, or towards the Scilly

* Milford Haven is 32 leagues to N.N.E. and though an excellent natural harbour when in it, yet its entrance is said to be with difficulty distinguished in hazy and dark weather.

Islands when homeward bound, and catched with contrary winds; I say for whatever cause it may have been advisable or necessary to come into this road, it is certainly very desirable that they should have a place of refuge in case they are catched with a hard gale of wind from N.E. while riding there; for to avoid this possibility, many ships are prevented from making use of the shelter the place naturally affords, and by that means meet with an unhappy fate, that might have been very safe in the road at St. Ive's, of which there are many examples.

Conformable to this idea, the island before mentioned stretches away finely to the eastward, and the Castle Point aims very naturally towards the south, but does not stretch away far enough to the south to make a sufficient cover for ships lying aground within the same from the swell that is brought round the points when the wind is at N.E. or N.E. by N. for this purpose it seems requisite that the Castle Point should be lengthened by art, which, if done in a proper degree, will afford a shelter for above 60 sail of ships from all winds; and to this design occur the following natural and considerable advantages.

1st. There is a great flow of tide, the spring tides in general rise and fall from 20 to 24 feet; extraordinary great springs flow 26 feet from low water, the smallest at least 18, which least flow, leaving at least 3 feet of water upon the sand at low water at and within the greatest part of the space included between the Castle and Penolver Points, it follows that there will be never less than 21 feet water at spring tides. A neap tide rises from 14 to 16 feet, and never less than 11, but, as there will be at least 7 feet water left upon the sand at low water, it in like manner follows there will seldom be less than 20 feet water at high water round the pier head, and never less than 18.

2d. It is observed that on the west side of the bay, where the road of St. Ive's is situated, that for three hours' flood from low water, the water runs into the bay in a direction N. by E. and after that, though the water continues rising three hours more, yet the set of the current changes to the contrary direction, so that the current sets out of the bay on this side nine hours, and into it only three; from hence arises this advantage, that if a vessel is too hard pressed in the road with wind at any point from N. to E.N.E. she can slip her cable, and sail within the pier whenever there is water, as well before as at or after high water; this set of the tide naturally tending to carry her thither, as also, if outward bound she can go out at half flood, and save half her tide up channel.

In short, every circumstance seems to invite the completing this harbour for the safety of ships where nature has been so bountiful, nor do I see but one untoward circumstance to hinder its perfection or annoy the same; and that arises from the great quantity of sand, of the species before mentioned, that is brought by the sea into that bay, which is formed by the island on the north side of the town: this sand being thrown up by spring tides becoming dry, and being of a light nature, is blown by the wind over the neck that joins the Peninsula to the main land into the harbour, and comes in such quantities as sometimes almost to bury the houses that stand on that part of the neck. There is no appearance, however, that this sand increases in the harbour, or stays there beyond a certain degree, which is somewhat variable according to the winds and tides; from hence it is washed into the bay, and from thence, part will be carried out to sea again by the reflux of the tides, and part in time crossing the bay by circulation, it is blown and heaped up in immense quantities on the S.E. side of the bay, and in and about the mouth of the Hale river at the bottom of the bay, which is now barred till about half tide, and would entirely be choked up thereby if not kept open by the great land floods. So that, upon the

whole, there is no appearance of the harbour or road being any otherwise than they now are in many ages, supposing all the solids to continue as they now are; but it may be reasonably expected, on the erection of a pier from the Castle Point, that a part of the sand that is blown over the neck into the harbour, and from thence now washed away again, may be intercepted by a pier, and there retained; and undoubtedly this in some degree must happen, yet with the precautions that I shall mention, and the provisions that I shall recommend, I am of opinion that the benefit to be expected from a pier ought not to be suspended on account of the inconvenience that may be apprehended from the sands.

In the first place, I would not recommend to carry out the pier further than is necessary to shelter such a number of ships as may probably require to lie in this harbour together; this I apprehend will be done with the length I propose, which is 60 fathoms.

2d. Had it not been on account of the sands, I should not only have proposed to carry the pier out further, but to have turned it more inward like the old pier; but this would, in a greater degree, have prevented the sands from washing out, nor can it be turned more outwards without lying the harbour too open, and exposing the pier to the direct shock of the seas.

It is probable, that, notwithstanding these precautions, the sands will be lodged higher on the inside of the pier than on the outside, as may be seen in the old pier, but yet like those, these will never increase beyond a certain degree, and as there will scarcely ever be less than 20 feet at high water at the pier head, some increase may be admitted without losing the expected benefit: this is exemplified at Scarborough, where a considerable quantity of sand is lodged within the pier, yet the utility of the pier, which has been the work of many years, and many thousand pounds, cannot be denied.

To diminish the quantity of sand that now comes over the neck, in case it is found to annoy the harbour, I would propose to build a wall 25 or 30 feet high, supported by proper buttresses, in the direction A B C, by which means the current of sand will be directed so as to go over the low part of the island north of the battery on the Castle Point, and be carried into the sea at the little cove between the Castle Point and the battery upon Meran Point, and thereby totally avoid the harbour.

I would also recommend the planting of the sea rushes which are found to entangle the sand, and thereby in great measure prevent its blowing, so that it would be retained in the north bay, where it arises, and increase the breadth of the neck of land that joins the island to the main land.

These things being duly attended to, I am of opinion that the harbour may be kept in a great measure, if not altogether, clear of sand, and if any remains, it may be driven out to sea by constructing a reservoir to take in the tide water, in order to make a scower at low water.

With respect to the construction of the pier, that will in a great measure depend upon the ground whereon it is to be founded; the immediate bottom where the pier is proposed, is entirely sand, such as has been already described, and is to an unknown depth: I endeavoured to perforate the same by a proper instrument, but there being 3 feet water over the sand at low water, though spring tide when I was there, it was impracticable to make so satisfactory a trial as might have been done had the sand been left dry. However, this far appears, that at a little depth under the surface, it lays so close and compact, that it was with difficulty that a sharp instrument could be got down 3 feet into the same. It is supposed that at some

depth underneath there is a rock or clay, and it is probable that the rocks which compose the Castle Point may reach under the sand to a greater extent than they appear above the surface, but it seems very uncertain whether any rock can be met with whereon to found the pier, the whole, or any considerable part of the length. I, therefore, in the following estimate, suppose that there cannot; and, therefore, propose to build the pier without any piles or wood-work, upon the principle which the French call *Pierre perdue*, or cast stones; that is to say, to drop a large quantity of rough stones in a proper direction and width, so as to form an artificial rock or base for the pier; these stones will, by degrees, sink into the sand, and being followed by others, these will rest upon the former, and so on till the first or lowest part becomes at rest; for the sand lying very close and compact underneath, will bear any weight when not affected by the action of the sea.

In this method a much greater quantity of stone will be needed than if the pier was built upon a regular base; but the whole of the base being of rough stones, the more irregular the better, of which great plenty may be got from the neighbouring rocks; as the whole will be done without timber work, and a large quantity of rough stones that would be needed to defend the timber work will be avoided, or rather compose a part of, and be included in the proposed scheme, it will, upon the whole, not only be much cheaper, but when well settled, more secure than any thing can be made upon a foundation of piles and timber upon the sand.

Upon these principles I propose to raise the pier to half tide, or even to the top, according as the materials are found to turn out: the principal use of this pier being a breakwater, or defence against the sea, the uprightness or lining of the inside for the purposes of a quay are less material; nor is it probable that it can be used for this purpose, as the spreading of the irregular stones at the bottom will prevent vessels from lying close home to the pier.

Having carefully viewed the several places from whence stones are likely to be got, and conferred with Mr. RICHARDSON, mason, who assisted me in this survey, upon the probable expense of winning, moving, and placing the same in order, I have accordingly formed an estimate of the probable expense, as follows.

ESTIMATE

For building a Pier in the Harbour of St. Ive's of 60 *Fathoms in length, according to the Plan and Sketch accompanying the same.*

The highest spring tides being 26 feet above the surface of the sand, the pier should be carried up solid at least 30 feet above the same, and supposing the whole to settle into the sand 6 feet, the whole height will be 36 feet, and admitting the sides to batter half the height of the pier on each side, and to be 24 feet broad at top, the base will be 60 feet, and the mean breadth 42 feet, or 14 yards; this multiplied by the height, 12 yards, produces an area or section of 168 yards in each yard running.

It is supposed that a pier built in the manner proposed with a parapet, regularly walled with Aberthaw lime, will be done at the price of 6*s.* 6*d.* per cube yard; but as the quantity of settlement into the sand is not quite certain, with other con-

tingences sufficiently to allow for those, I estimate the whole at 7*s.* 6*d.* per cube yard, and this, for 168 yards section, comes to 63*l.* per yard running.

	£.	s.	d.
To carrying out the pier 120 yards, at 63*l.*	7560	0	0
The parapet to be 9 feet high, 7 feet base, and 3 feet top, the mean thickness will be 5 feet, and contain 5 yards section, which, at 7*s.* 6*d.* per yard cubic, is 1*l.* 17*s.* 6*d.* per yard running, and which for 120 yards is	225	0	0
To extra work in finishing the pier head, cramps, iron, and lead	200	0	0
	£.7985	0	0

Austhorpe, October 25, 1766. J. SMEATON.

TOPCLIFF MILL.

The Report of John Smeaton, Engineer, upon the Practicability of removing Topcliff Mills, Yorkshire, to Assenby Stream, below Topcliff Bridge, consistent with the proposed Navigation of the River Swale.

Having viewed the situation of Assenby stream, as also the present situation of Topcliff mills, I am of opinion as follows:—

1st. That, exclusive of the dam, which is totally ruined, the mill appears to be in bad repair, and built upon so bad a principle for doing business, as to be incapable of any considerable improvement, without entirely rebuilding.

2d. That the situation of Assenby stream is preferable to the present one, as there may be a better fall.

3d. That, supposing the mill and dam to be entirely rebuilt, the only difference, in point of expense, in the present situation, or at Assenby stream, will be in the carriage of the old materials from the old situation to the new one, and in digging the cut at the new situation, and perhaps some additional charge about the mill-stable and out parts of the mill-house, which, in its present situation might possibly be saved.

4th. That the removal of the mill and dam will be equally if not more beneficial to the navigation at Assenby stream, than in its present situation, because it seems to me, that a dam raising the water 7 feet, or thereabouts, at Assenby stream, will pen the water up to the same level of the present mill, as it has ever been penned by the dam before it was destroyed; and by building a dam at Assenby stream, the navigation dam below needs not be raised so high as it otherwise must be, in order to float the vessels over the shoal at Assenby stream in dry seasons.

Northallerton, 14th March, 1767. J. SMEATON.

EYMOUTH HARBOUR.

The Report of John Smeaton, Engineer, upon the Harbour of Eymouth.

The harbour of Eymouth lies at the corner of a bay, at which ships can work in and out at all times of tide, or lie at an anchor secure from all winds, except the northerly or north-easterly. From this circumstance its situation seems very ad-

vantageous; but as the mouth of the river or harbour lies open to the northerly winds, ships cannot lie in safety therein without going up beyond the elbow of the present quay, where the water being shallower by several feet, and the breadth much contracted, the harbour is not only defective in point of capacity, but in safety also; for at a full sea the mouth being wide, the sea tumbles in with so much impetuosity, that great seas find their way round the elbow, and make the vessels even there lie not so quiet as is to be wished: in order, therefore, not only to enlarge the harbour, but very greatly to increase the safety of vessels lying therein, it is proposed to build a north pier to defend the harbour's mouth, and to this end nature has furnished a ledge of rocks, not only capable of making the most excellent of all foundations for such a pier, but in as advantageous a situation as could be wished, upon which a pier is proposed to be built according to the plans accompanying this report; for, according to the directions therein specified, the harbour will be defended from all such seas as annoy the bay, and the only point from whence the harbour could be affected by seas coming in through the mouth, are land-locked by the points of the bay; so that the harbour will, in its whole extent, be perfectly safe in all winds. It is also to be noted, that the same circumstances that concur to make the harbour safe in all winds, afford the vessels means for getting in and out at all winds:* and this proceeds from the entry into the harbour lying nearly at a right angle with the direction into and out of the bay; it is also a great advantage that here is a good flow of tide, which at spring tides is said to be 20 feet, and there is at the lowest ebb several feet of water at low water between the proposed pier-heads, so that there will be seldom less at neap-tides than 16 or 17 feet water in the harbour, which is capable of receiving vessels from 300 to 400 tons, according as they are more flat or more sharp built, and which afterwards can, upon a greater flow of tide, be got into a more advantageous birth.

Another advantage to the executing the proposed design, arises from a great quantity of rough rocks that lie at the north-westerly point of the bay, very proper for building the outsides of the body of the pier, the inside of which may be done with rough stones, won or blasted from the neighbouring rocks to that upon which the pier is proposed to be built; by this means, the pier may be executed at a trifle of expense, in proportion to the extent and utility of the design; for the rocks that are represented within the intended pier will be removed and made smooth, so as to procure an addition of harbour-room, at little or no charge, as they will be used within the pier: when this is done, there will be an addition of harbour room in the space between the elbow before mentioned and the pier heads, capable of holding 30 ships of middle size, with sufficient passage, and which in time of war will be very useful on this coast, not only for the refuge of coasters from the enemy, but in bad weather for privateers and the smaller sized vessels acting offensively.

* 1st. If the wind is right a-head to vessels coming into the bay, it will of course be smooth water, and there being room enough to turn, they can work in till they are near the bottom, and then sail with a fair wind right into the harbour. 2d. If a vessel comes into the bay before the wind with a great sea, she will also have the wind fair to sail into the harbour. 3d. If the wind is right a-head to her going into the harbour, she will have a fair wind into the bay with smooth water, so that after coming to an anchor, she can warp herself in. 4th. In like manner a vessel that wants to go out, if the wind blows right into the bay, she will have a fair wind out of the harbour, and having room in the bay, can work herself out to sea, unless it blows so hard as to bring on a great sea, and if so, it would be undesirable to be out at sea upon a lee-shore. 5th. If the wind is right a-head to a vessel desiring to go out of the harbour, as the bay will be smooth, she can warp out, and being out, has a fair wind out of the bay. Lastly, a vessel going before the wind, out of or into the harbour, will have a fair wind out of or into the bay respectively; and a vessel going before the wind, out of or into the bay, will have a fair wind out of or into the harbour respectively.

What relates to the method of the work itself, will be sufficiently explained by the plans and estimate; I have only to remark, that I do not mean to fix the place of the pier to such precision, as not to be subject to be somewhat varied.

If it is found convenient, on account of fixing the base, to be a little more in, or a little more out, or the head somewhat nearer or further from the present head, than specified in the plan, I expect the surveyor to use his judgment therein.

Also, I do not mean that the ground course of the stones forming the base of the pier should be exactly in a right line, or the bases cut to the same level, or answerable to any given delineation lengthways of the pier; all I desire is, that a bed be cut for each stone declining towards the middle of the pier, as shewn in the plan, but they may be upon different levels, and a little more in or out, as best suits to get a firm footing for each particular stone, which stones must be suited in their sizes and thickness accordingly.

In regard to the repairs of the present pier and quay, where it is necessary to begin at the bottom, I advise to drive a row of piles 6 inches in thickness, and close together, edge and edge, and the heads being connected by a string piece, to let the ground course of stones be notched upon them as was done at Coldstream Bridge. The rest of the quay will be defended by laying a tier of rough stones, sloped up against it at the foot but not so as to be in the bilgeway of the ship.

This would be still more effectually done by driving a row of piles either close together, or at most but 9 inches distant from one another, and at about a yard distance from the foot of the pier, so as not to be in the way of the vessels, and to lay a slope of rubble-stones against the foot of the pier, between the pile-heads and the wall, as before described, observing always to slope the rubble down stream. This I think the best way of securing the present quay; but as it will be altogether defended from sea-ward by the proposed pier, and as the last proposed defence must be attended with some expense and trouble, being only done at short intervals of the tide, I advise to cut the matter of repair short by laying stones only, and take a trial of this till the north pier is built.

Austhorpe, May 2, 1767. J. SMEATON.

ESTIMATE

For Eymouth Harbour. The expense of building a North Pier.

		£.	s.	d.
The length of the outside, from the elbow and round the head into flank within, is 240 feet, this multiplied by 22 feet mean hight, produces 5280 feet superficial, and this by 5 feet mean thickness, produces solid	Cube Ft. 26,400			
The length within, from the elbow to the said flank, is 132 feet, which multiplied by 22 feet high, is 2904 feet superficial, and by 3 mean thickness, gives	8,712			
Total solidity of the first stretch next the head	35,112			
It is said, that such works as are represented in the inside can be brought from the rocks and laid in place at 6*d.* per foot, but as I understand this of the loose rocks already quarried, and as the quantity so produced may be short of the whole, and the quarrying is supposed to cost 2*d.* per foot extra, therefore, to make a sufficient allowance, I make 7*d.* per foot on the whole: the outside, the workmanship will be more rough, but the stuff being supposed larger, and worse to place and handle, I reckon on that also 7*d.* per foot,				
To 35,112 cube feet of stone in the outsides, at 7*d.*		1024	2	0
Carried over		1024	2	0

		£.	s.	d.
Brought over		1024	2	0
The whole circumference being 372 feet, this, multiplied by 3½ feet mean breadth of the basement course, produces 1302 feet superficial; this quantity of the rock will be required to be cut sloping towards the middle of the pier, and being tide-work, and the rock hard, I allow				
To 1302 feet superficial of rock cutting for basement, at 8*d.*		43	8	0
The length of the above being 173 feet, the mean width 24 feet, and mean heigth 22 feet, the whole contents, in solid, will be	Feet. 91,344			
From which deducting the outsides	35,112			
Remains for the solidity of the inside filling	56,232			
which is equal to 2083 cube yards.				
To 2083 cube yards (after deducting the outside blocks) of filling with rough stones,* to be placed by hand, and well packed, at 4*s.* per yard		416	12	0
To 172 feet length of parapet, mean thickness 6 feet, and 9 feet high, produces 344 yards solid, which being well walled and filled with mortar, and built of free-stone rubble, I allow 7*s.* 6*d.* per cube yard		129	0	0
To hammer-jointing and facing both the outsides, containing 3268 feet superficial, at 1*d.*		13	12	4
The cordon, being 172 feet long, and 2½ feet in breadth, and 1 foot thick, will contain solid	430			
The capping, being 174 feet long, 3 feet broad, and 1 foot thick, will contain	522			
Sum	952			
To 952 feet of Leimerton stone, worked, and laid in place, at 1*s.*		47	12	0
To flooring for the top of the pier, being 172 feet long, and, at an average, 6 feet broad, containing 1032 feet superficial of the same stone as the outside of the pier, at 8*d.*		34	8	0
To stone posts for mooring		5	0	0
For 173 feet of pier next to and including the head		1713	14	4
The length of the pier, from the elbow to Gunsgreen Point, being 181 feet, upon a mean height of 13 feet, the superficies will be 2353 feet on each side; and allowing the mean thickness on the outside, 4 feet, and the inside, 2½ feet, the mean thickness of both sides will be 6½ feet, and the whole solid formed thereby, 15295 cube feet, at 8*d.*		446	2	1
To 724 feet of cutting the rock for the basement courses, which being less in the tide's way, I reckon at 6*d.*		18	2	0
The outside blocks being deducted from the solid contents, there remains for filling 1046 cube yards, which being more out of tide's way, I estimate at 3*s.*		156	18	0
To free-stone rubble walling in the parapet, being 8 feet mean base, 2½ mean top, and 7½ mean height, contains 264 cube yards, at 7*s.* 6*d.*		99	0	0
To hammer-jointing and facing both the outsides, containing 2896 feet superficial, at 1*d.*		12	1	4
To hewn work of Leimerton stone in the cordon and parapet, the cordon being 2½ feet broad, and the parapet the same, and 1 foot thick; this, for 181 feet running, contains 905 cube feet at 1*s.*		45	5	0
To flooring the top of the pier between the parapet and aisler, the mean breadth being 5 feet, will contain 905 feet superficial, at 8*d.*		30	3	4
To rough stones to be laid in the angle of the pier, adjoining the land at Gunsgreen Point		3	0	0
For 181 feet of pier from the elbow to the point		810	11	9
For 173 feet ditto next and including the head		1713	14	4
Sum		2524	6	1
For contingent expenses I generally allow 10 per cent upon the whole		252	8	7
		£.2776	14	8

N.B. As the rocks within the pier-head will be got and made use of in filling the pier, I suppose this to be included in filling of the pier; but if fender piles should be thought necessary within the pier for vessels to rub against, the expense of those must be added.

* All stones in the filling are proposed to be put in whole, unless they arise of above two tons.

STONEHOUSE CREEK BRIDGE.

Method of Construction of the Bridge over Stonehouse Creek, as designed by JOHN SMEATON, *Engineer.*

ON the Stonehouse side of the bridge there appears, from the borings and soundings made by Mr. JOHN MUDGE, to be a good hard clay bottom, which gradually declines from the quay towards the middle of the creek, but which, at the further side of the channel at low water, is 20 feet deep below the mark of low water spring-tides; from thence for the space of 250 feet, that is, till within about 80 feet of the opposite shore, the clay bottom can no more be felt with sounding rods of 26 feet long, which were the length of those made use of, so that, for the aforesaid space of 250 feet, the depth of the mud is not known; but, from the manner in which it declines from each side, it is not unreasonable to suppose it to lie somewhat like the line dotted out in the plan, but whether this be so or not, the depth of the mud is assuredly so great, that to found the whole upon piles would be so very expensive, as to render the construction in that respect impracticable. It is, therefore, proposed, by removing the water-way about 50 feet nearer the quay than it now is (that is, the middle of the arch to be about 100 feet distant from the quay), to take the advantage of the rise of the clay bottom, in order to found a couple of piers whereon the arch may solely depend, and to make the rest of the passage over the creek by forming a rampart with rubble stone, and quarry rubbish cast upon the surface of the mud, and heaped upon till the stones first cast, either ground themselves upon the clay bottom, or by consolidating the mud by mixing therewith, shall make an artificial foundation capable of sustaining the incumbent weight of materials above the surface of the mud; for this purpose, the piers of the arch being built square on the outsides next the ramparts, and quite upright, no settlement of the rampart will affect the piers, nor will any of the work of the ramparts be displaced in settling by encountering with any projection of the piers, nor will any damage ensue to any part of the work by such settlement, but what may be restored by addition at the top; and as there is plenty of rubble to be obtained on the side next Plymouth Dock, a considerable part of which would have been necessary to have been removed for the sake of forming a proper slope for the road up the hill, it is expected that this rampart may be formed at a moderate expense. The work of the rampart may be begun immediately; I will, therefore, first describe the manner in which I would propose to carry it on, subject, nevertheless, to such alterations as difference of circumstances arising from the process of the works shall indicate.

I would propose, then, to begin at the end where the matter is to arise, bringing forwards the materials in wheelbarrows or carts as shall be found most convenient, merely to tumble them over the creek, observing to reserve the heaviest and best stones for the outside, the second best for the bottom, and the rubbish for the middle: I would advise to carry forward the work to its full height nearly as it advances, by which means the whole will obtain its full settlement in the least time. The breadth at top, and slopes therefrom, being as per section, the several widths at the surface of the mud, will be had by consulting the outermost ground lines of the plan; and as the work will begin from the shore, the additional width to begin with, in order to allow for settlement into the mud, will be found by experience as the work goes on.

The section of the rampart shewn in the design being adapted to the line *A B*, near the middle of the present channel, and supposing it to ground upon the clay bottom there, the beginning ought to be 72 feet wide, as therein shewn.

When the work is advanced some distance from the south-west side, and the mud grows deep, if it is found to swallow up a greater quantity of matter than is expected, it will be proper, by way of making a kind of bond or platform for the base, to stake down a double thickness of fascines or faggots upon the surface of the mud, and then proceed to throw the stones upon it, as is represented in the section; this will be not only a likely means of keeping the base from spreading as it goes down, but of producing an equilibrium sooner, in case it should not be found to go to the bottom where the mud is deep.

When the core of matter is found in some measure to come to rest, in order to get the proper breadth at top, it will be necessary to begin at the surface of the mud, and dispose the larger materials by hand, so as to form the slope or batter shewn in the section, which is nearly that of $\frac{1}{3}$ of the perpendicular above the surface of the mud, and is supposed to be the slope of an equilateral triangle below the same.

With respect to the founding of the pier, as the deeper will be near 10 feet below the low-water spring-tides, I apprehend it will be quite impracticable to get down to the clay without incasing; I, therefore, would propose to encompass a square area, capable of just containing the base of each pier, with a single row of dove-tailed piles, of 4 inches in thickness, to be driven a foot or 18 inches into the clay, more or less, as they are found to go harder or easier, and of a sufficient height to keep out the neap-tides; that is, about 16 feet long, the heads of them to be regulated at top by strong pieces within, and supported by beams across, which may also be done in one or two tiers below, as shall be found necessary to support the pressure; which lower beams must be made movable, and taken away as the work advances.

The mud below its surface will render the piles water-tight, and, if not found so above, may easily be made tight, by throwing in some baskets of coal-ashes, close to the piles on the outside, when the water lies against them.

As I do not expect the bottom to be level, it must be reduced thereto by forming one or more steps, as shall be found most convenient, observing to form the flat of the steps rather inclining towards the hill; and, unless the matter happens to be so hard, that the piles cannot be drove therein full 18 inches, I would have the ground course next the water-way of the arch, and the returns thereof, laid, at least, 1 foot below the natural bed of clay, that the gulling of the water (which will soon carry away the soft matter down to the clay) may not easily get under the foundations of the piers.

When the first pier is raised sufficiently above low-water mark, the piles may be drawn, and made use of in like manner for the other; and if there appears to be the least danger of the gulling of the bottom by the water, I would advise a part of the piles, of which the dam has been formed, to be cut to a proper length, and placed in the groove already formed, so as to be driven down, or cut off below the surface of low-water spring-tides; this to be done in the face of the piers, next the water-way, and the returns of the angles, but to the remaining parts of the piers it will be useless.

As this business will be tide-work, except at neap-tides, it will be necessary to procure one or more good chain-pumps, in order that the cavity may be expeditiously cleared of water; it will be advisable to have a couple of upright square pumps, of about 8 inches (as they will stand in less room), to keep the water out after the bulk is evacuated, and for the standing of which an upright groove or recess may be formed in the back side of the piers; I advise two, that one may be in order, while the other is cleaning or repairing.

The arch, the facings, cordon, and capings, I would propose to be of Portland

stone, the rustic part of the pillars of moor stone, the body of the parapet over the arch of Plymouth marble, cut aisler, the spandrills of the arch of the same, either coursed or rough, as may be thought most proper, and the body of the piers below the rustic may be aislered, either with Plymouth marble or moor stone, as may be thought proper on account of price; but if no great difference, I would advise moor stone, as taking more kindly to the mortar, especially where constantly wet. The whole of the inside core I propose to be of rubble from the neighbouring rocks. It will be advisable to set the whole outside up to high-water neap-tides with Watchet or Aberthaw lime, and it would, as Plymouth lime is very tender in water, be also very advisable that a quantity of the aforesaid lime was procured to mix with that of Plymouth for the inside work to high-water spring-tides: this is the more necessary, as Plymouth lime and marble do not seem disposed to form of themselves a very compact body, when constantly subject to the water.

Not having a plan of the quay at Stonehouse and housing adjacent, I have drawn the bridge straight; but as it may probably be found more suitable and convenient to make the rampart somewhat curved from the arch and termination upon the quay, I leave this to the determination of those concerned in the execution upon the place.

The above is, I think, the most material of such directions as at present occur, and which, I hope, will be found sufficient for beginning; if any thing is not sufficiently explained, shall be ready to do it by letter.

London, June 15, 1767. J. SMEATON.

LINTON DAM AND SWALE NAVIGATION.

The Report of John Smeaton, *Engineer, upon sundry points relative to the Linton Dam and Swale Navigation, referred to his consideration by* John Smeaton, *Engineer for the said Works; by Order of the Commissioners.*

The points were the following:

1. Whether any, and what allowance may be made for the declivity of the rivers Ouse and Swale in dry seasons, so as to depend on making a depth of water beyond the dead level of the height of the dam.

Answer. It is the practice of engineers in levelling to allow one inch per mile for the least sensible current, and this I apprehend may be safely allowed, but not more; I do not mean that there can be no current, under an inch in a mile; but that all methods of levelling are so precarious, where such minute differences are concerned, that it is as safe to make that allowance as to rely upon any other method to prove it, especially as it is easy in practice to remedy the defect by adding a rib of wood to the crown of the dam, in case its height should be found defective by a few inches.

2d. Whether the height of 11 feet above the surface of low water at Linton is necessary for the dam there above that surface, in order to make good the water to the mark near Milby Staith, which, according to his levelling, he makes to be 11 feet above the said low-water surface at Linton.

Answer. The difference of 11 feet between the mark at Milby, and the low-water at Linton, is precisely the same that I made it; which I particularly remember, having explained it to the committee in London, how I came to expect to raise the water to my proposed height at Milby by a 10-foot dam at Linton, observing that the distance being eight or nine miles, according to the common allowance of an inch per mile, that would make so many inches, and the remainder would be made by the thickness of the sheet of water going over the dam. I still remain of opinion,

that, for the same reasons, if the dam at Linton, its crown is raised within one foot of the dead level of the proposed point at Milby, that the water will rise to its mark, at least so as it may be helped by a rib of wood as before mentioned, it being impossible to take levels with absolute certainty for so great a distance. It is, however, to be remembered, when my plan was originally projected as above, the Linton dam was supposed one undertaking with the Ure, and being no more than a general design to shew the practicability, the utmost accuracy was not wanted; but as it may prevent any jealousy between the different parties interested if the Linton dam is raised within half a foot of the dead level of the mark at Milby, I think it cannot fail to raise the surface of the water in its driest seasons to its mark at Milby.

3d. Whether the design prepared by Mr. SMITH for the dam at Linton is a proper one for the purpose.

Answer. The design exhibited is, I apprehend, upon the same principles as that at Naburne, but with improvements; and as that at Naburne has stood the test for several years, I cannot doubt but this will do the same if executed with the same care and judgment. It would seem to me to be more unexceptionable if the base was enlarged by 6 feet, and the top diminished by 6 feet, the lowest step to be raised 2 feet above low-water, and the ascent from thence to the top to be divided into three equal steps instead of two. The greatest objection I have to this construction regards expense. It is greatly different respecting the body of the dam from what I proposed, and with the principles of my proposed construction; but I have acquainted Mr. SMITH, where the reputation of an artist is concerned in the success of his works, he certainly ought to proceed upon his own ideas, and not those of another. This is certain, had the navigation been opened before the Linton lock and dam were begun, which was the declared preliminary of my original estimation, in order to bring down stone from above for the construction thereof, that it would have been erected at a much less expense; as it now is, it may be a matter of computation into which my present occasions will not permit me to enter.

4th. Whether the design for Linton lock is properly adapted.

This lock is, I apprehend, upon the same construction as I have seen several by Mr. SMITH's father, built several years ago, and which have stood and answered very well; the principal articles, in which I differ in grounds where I use wood bottoms, are the following.

1st. A bearing pile under each sill, ranging in the face of each wall (but this is rendered less necessary by a sheet of piles, in Mr. SMITH's construction, under the face of each wall); a ditto under each sill answering the middle of the chamber, and if the ground is more soft, a pile under the outward end of each sill.

2d. The great sill for the lower gates, the pointings framed therewith under the thresholds, in order the more firmly to be bolted thereto.

3d. A double row of rabbeted piling at the lower gate-sill to prevent the passage of the water in case the chamber-floor should become defective.

4th. The coffin stones made alternately long and short, broad and narrow, in order to prevent their walling joint and joint, as it seems to me must be the case if made of one dimension, as prescribed by Mr. SMITH.

5th. In good gravel bottoms, where stone is cheap, I have used it instead of wood, still keeping a row of piles under the face of the walls, with a riband or string-piece upon their head, two good rows of rabbeted piling under the lower gate-sills, and a row of ditto at the tail of all.

The masonry of the lock in general seems well designed, and substantial; but after all designs, good execution is a great matter.

KNOUCH BRIDGE MILL.

Proportions and Directions for building the Mill at Knouch Bridge, by JOHN SMEATON, *Engineer.*

The two water-wheels for common use to be 11 feet 6 inches diameter, out and out, and 8 feet wide, the shrouds to be 9 inches above the soal, and to have 36 buckets, the rising boards to be 4½ inches broad, and the breadth of the bucket-board such, that the point of one bucket may advance to the centre line of the heel of the next bucket, and the cutting edge to be thrown to the outside.

The bucket-boards should not be of above 1 inch in thickness, and to strengthen them, I recommend a shroud in the middle; the construction I commonly use in wheels of this sort, is three pair of clasp arms with three rings, and then to put on the boarding of the soal parallel to the axis, so that the boards are nailed down upon the rings like a floor upon joists. The wheel-case or race to be made to a true sweep, answerable to the wheel, to be continued from the lowest point under the axis for a quarter of a circle, ending at the height of the centre, above which the breast wall to be continued upright to a proper height for supporting the trough, which, if thought proper, may be made of stone to the front of this breasting. The water, in taking the wheel, shoots backwards, so that the wheel turns the same way round, and the water is delivered at the tail, as an under-shot wheel; the water is drawn by two shuttles, answerable to the partition shroud in the middle of the wheel; but as it is impossible to describe the particular form of the trough, so far as relates to the drawing on of the water, without a draft, this shall be supplied in due time.

The water-wheel being 11 feet 6 inches diameter, there will remain 2 feet to complete the whole difference of 13 feet 6 inches; the whole height required for the surface of the water above the top of the wheel being only 1 foot 6 inches, there will remain 6 inches either to be added to the head of water, or to admit the bottom of the wheel to be laid 6 inches out of tail water, or to be expended partly one way and partly the other, according to the judgment of the artist.

NOS. FOR THE TWO OVER-SHOT WHEELS.

The great cog wheel	64	at 5½ inches pitch.
The great lantern upon the upright axis	25	
The spur-wheel upon the upright axis	72	at 3⅛ inches pitch
The 5-feet graystone lantern	19	
The 4-feet cullens or blue stone	15	
The 3-feet 10½ French stones	14	
The 3-feet 7 inches cullens or blue stones	13	
The 5-feet graystone for shelling oats, its lantern	15	

N.B. The numbers above being put upon the spindles of each pair of stones respectively, and all being supposed to be placed round the spur-wheel, they would all go at their proper paces if driven together; therefore, they may be suited together to either mill, as best suits the convenience of the miller.

For the flood-mill, it being proposed to remove one of the present water-wheels from the Whiston old mill, which are 14 feet 8 inches diameter in the ring, I propose to continue the same number of floats as at present, but to alter the mortices, so that the starts may hold the floats pointing to the centre.

The float-boards to be 1 foot broad, and so as to form a circle of 17 feet 4 inches, the rest of the space to be filled up by oblique breast-boards like the wheels at

Kilnhurst forge; but shall shew the particular degree of obliquity, by a draft along with the trough for the over-shots.

The width of the wheel may continue the same as at present, viz. 5 feet 2 inches, but if it can conveniently be augmented to 6 feet, it will be the better.

The flood-wheel I propose to be a breast-wheel, and to be laid 7 feet below the full head, viz. the nose of the gate to be, when shut, 2 feet below head, and 5 feet fall; now, as this will make the bottom of the flood-wheel 6 feet or 6½ feet above the common tail-water, and as this wheel will do business with 3 feet or 3½ feet tail-water, it follows, that it will do business when this river is from 9 to 10 feet higher than in its ordinary state.

The numbers proposed for this wheel as follow:

The great cog wheel	84 cogs	at a 5-inch pitch.
The greatest lantern on its upright axis	25	
The spur-wheel on the upright axis	72	at a 3½-inch pitch.
A pair of 5-feet gray stones	19	
A pair of 4-feet cullens	15	

N.B. If any other sorts or sizes are thought proper, the numbers or the spindle lantern will answer, if made respectively the same as those for the over-shot wheels.

The over-shot mills above proposed will both be turned at once, with the same quantity of water wherewith one of the wheels of Whiston old mill was worked when I was there, and which was said to be about the whole quantity in dry seasons. This quantity will enable each of the over-shot mills to grind with great ease at the rate of a quarter of wheat per hour, that is 16 Winchester bushels per hour by the two wheels.

The breast-wheel will grind the same quantity as either of the over-shot wheels, but will require a double quantity of water, that is, it will require as much water to grind eight bushels per hour, as both the two over-shot wheels will require when grinding at the rate of eight bushels each; but as the two over-shot wheels will work at the rate above mentioned with the common summer's water, I apprehend it will seldom happen but there will be water to spare, and, therefore, it may be worth while to consider whether one of the over-shot wheels may not be omitted, and the breast-wheel used in short water times in its stead, and by that means the breast-wheel be brought to act in a double capacity, as a short-water wheel as well as a flood-wheel.

The over-shot wheels will work with 3 or 4 feet tail-water, at which time there will be necessarily such plenty, that it will be very immaterial whether the breast-wheel takes more or less.

London, 15 *June*, 1767. J. SMEATON.

P.S. If the staves of the great lanterns are made of cast iron, as will be advisable, they may be made of a flattish or oval figure, and thinner than if made of wood, so as to give room for a stronger cog.

The following sketch respecting the situation will, I hope, make the whole clear.

RIVER COLN.

Plan for ascertaining the proportional Quantities of Water flowing down the high Stream and Iver Stream, being two Divisions of the River Coln below Uxbridge, from whence also may be determined the Quantity of Water discharged at each Place per Hour.

The sketch annexed is solely explanatory, to save many words in description, and is, therefore, supposed not to be drawn from a scale.

The point A shews that branch of the river which comes from under the western-most bridge of Uxbridge; this is not the whole of the river Coln, a considerable stream being diverted therefrom, called the Cowley stream, which crosses the great western road nearer the body of the town.

Below the point A the branch in question divides, one part turning the water-engine or colour-mill, and seems to have been an artificial cut, but the greater part of the water goes down the old river; those streams unite at B, and are again divided at C into two streams, called the high stream and Iver stream, the former being much the largest; from the point of division C the water runs with a gentle current to the bridge D, where, meeting the ford where the road crosses, and being somewhat pent up, it runs more rapid from thence to E, where this branch sub-divides, but afterwards unite and join with the stream before-mentioned.

From the point C the Iver branch runs with a very languid current till it meets the island F, after which it runs more briskly, as, also, at the bridge and ford at G it runs again languid till it gets into the inclosures, and then more briskly through the inclosures till it gets to the second bridge at H, where there is a further obstruction and fall, and from thence it runs to Iver mill.

Now, if a water-gage is erected upon the high stream, and another on the Iver stream at any place so far below the point of separation at C, that the water running from C to D, and from C to G, shall not be interrupted in its natural course, then those water-gages will respectively shew the proportion of the two streams, and afford a means of computing their real quantities, independent of any inquiries or evidence to be collected from the millers, and which may be executed in the following manner; upon the branch of the high stream E L, and near the point L, let a water-gage be erected of 30 feet in width, the sill whereof to lie even with the common surface of the water in dry times, to be terminated by two upright posts, and if need be, one in the middle, so to divide the same into two passages of 15 feet each, the whole to be made close and tight underneath the sill and on each side the posts, so that no water may pass during the use thereof but through the 30-feet passage over the sill, and, consequently, will fall over the same like a tumbling-bay. While this is erecting, the water may be turned through the passage E M, which will go to the mills as at present, but when completed, the water, being stopped from going through E M, will wholly be obliged to pass the water-gage at L, and will raise the water there so little as not to affect the run of the water from C to D. Now, as the Iver stream runs more languid than the high stream, it will be necessary to go somewhat lower down, suppose to the bridge H, a little above which at N let a similar gage be erected, but with this difference, that as the Iver stream is not supposed to be above half the currency of the high stream, a gage of 15 feet will equally carry the water. As this width will not occupy the whole river there, the

N.B. The water-course I R seems intended to discharge the overplus water in times of floods from the Iver stream into the high stream, the mouth of the passage at I being stopped up with piles.

gage may be erected on one side, while the water let down to the mills on the other side, and being completed, the bye-passage must be stopped up, and the whole of the water be obliged to pass the water-gage, as in the other.

Now, upon turning the water through the two gages, if the depth of the current water upon the sill is equal, then the quantity will be in proportion to the widths; that is, that the currency of the high stream is double the currency of the Iver stream; but as the depths at first trial will probably be found unequal, let as many boards be put into that gage (end-ways up) upon which the water runs shallowest, as by straightening the water-way will cause it to run of equal depths with the other; then will the proportional quantities be as the widths respectively, when so adjusted: and this will be shewn by inspection, according to the various states of the river in dry seasons, whether the mills are drawn or not, and the experiment may be continued (with a proper attendance) for a month, or such time as shall be thought necessary; and account being kept of the depth of the water at different times, answerable to given widths, will afford a means of computation of the real quantity in tons per hour; but the computation of the real quantities is more matter of curiosity than use in the present case, for as the proposition is to take away no more water from the confined stream at A, than is due to the Iver stream, in any one given state, therefore more especially in the lowest state, it will follow, that if the whole river at A was afterwards parted by a gage, similar to those in the experiments, whereof that representing the Iver gage is conveyed to London, and the other to be conveyed down the high stream, after the Iver stream is stopped up by a dam, then will the high stream remain with its present quantity of water as heretofore, nor will it be surcharged in time of floods for want of passage down the Iver branch: because, whenever the river at C rises so high as to afford more water than the mills can use, the stop or dam upon the Iver being made in the form of a tumbling-bay, the surcharge will be conveyed down the Iver, and for several months in the year will be a considerable running stream.

It will be necessary also to put a small gage upon the little brook that falls into the Iver at the bridge C, which, when reduced to the same depth, must be deducted from the width of the gage at N, and the width so reduced, in comparison with the gage at L, will give the true proportion of the separation of the waters at C, and of the proposed separation at A. Again, as a quantity of water is proposed to flow down the Iver stream, in order to supply the neighbouring meadows, villages, and the town of Colnbrook with water, whatever the aforesaid little brook shall exceed or fall short of what shall be thought proper for that purpose, a due allowance can be made in the width of the gage proposed to be erected at A.

It may be objected, that when the water due to the Iver stream is deducted from the river at A, that then the engine or colour-mill will lose a proportionable quantity of water; but as the water flowing down the main stream is not employed in working any mill before this reunion, if, in dry seasons, the main river is straightened, in the same proportion by a flood-gate to be erected at O, and to be drawn up in times of floods, then will the engine or colour-mill be in all respects in the same condition it now is.

It may also be observed, that the obliging the river to pass the water-gages at A, may, in floody seasons, pen the water upon the tail of the mills just above the bridge of Uxbridge; but as this partition will only be of use in dry seasons, it is proposed, that there shall be a set of flood-gates, that being drawn up, shall leave the river as capacious as it is at present, and, consequently, the mills in the same condition; it is also proposed, that the water-gage at A shall not be erected so as in

dry seasons to pen up the water above the bridge of Uxbridge higher than it now is, so that the mills above the same shall not, in any season, be affected by the proposed undertaking. It is supposed, that this method of the partition of the water is (if possible) more unexceptionable than that of taking a given quantity out of the river or colour-mill head near A, as formerly proposed; but that if this method be thought more eligible, as the gages above mentioned will afford a just method of computing the real quantity of water discharged by the Iver stream, a quantity may be taken by the method already exhibited, which shall never exceed the just proportion in the driest seasons, and in all others rather fall short than exceed it, and still the surplus-age, when too much for the mills and grounds, be discharged by the Iver stream in the same proportion as heretofore.

Austhorpe, July 8, 1767. J. SMEATON.

PORT GLASGOW PUMP.

Description of a Pump for the Dock at Port Glasgow.

The water left in the dock at a medium to be evacuated by pump-work, as taken the 22d day of August, 1767, was

Mean length	243 0	Solid contents, 21141 Cube feet = 627½ tons.
Mean breadth	36 0	
Mean depth	2 5	

This quantity to be raised in 4 hours to the mean height of 4 feet will require 6 men working at a time, and good English labourers will continue at the same rate for the whole time; but as the labourers to be employed will probably be such as can be promiscuously picked up, it will be proper to have two sets to relieve each other.

The distance of the chains from the axis of the lever to be $\frac{1}{3}$ of the length of the lever; it would be most convenient to have the centre of the chains 2 feet from the centre of the lever, but should not be less than 1 foot 6 inches.

The diameter of the working barrels to be 17 inches; and it would be well to have them lined with cylinders of hammered brass or copper, as iron will rust in salt water, and the bare wood will chamber too fast.

In the working of this pump it is to be noted, that when the height of the water without exceeds the height of delivery, that it will never rise higher in the mounting pipes above the chamber than just to force its way outwards, so that the water will never be raised to any height that is unnecessary, and with a proportional addition of force will throw out the water at all times of tide.

The 2 barrels A B are connected together by a square box or trunk C D, into which are 2 square passages through the working barrels E F, about 8 inches high by 10 or 12 inches wide; in the foreside of the box is a hole 10½ diameter, so as to receive a pipe of 8½ or thereabouts, which pipe is to be rammed tight, and to lie through the wall or bank into the open sea, the outward end of which may be guarded by a valve, if thought necessary; but if the lower valves of the pump are tight, no water can revert into the dock; it will, indeed, rise to an equal height in the mounting pipes, but will there be at rest.

The buckets I would propose to be made in the same way as those for fire-engines, and the lower valves to be made double; I propose them to be framed upon

a cast-iron plate, closing up the bottom of the barrel, and which may be screwed to the barrel by 6 or 8 bed-screws, the nuts of which to be let sideways into the wood.

H H H H are blocks for the pumps to rest upon.

The iron rods and buckets will, I expect, be of weight sufficient to carry them down, but they should be steadied by passing through a plug or collar in the top of the mounting pipes.

The valves must be made light, particularly of the buckets, that they may meet with the less check in descending, and the whole leathered with pliable leather, which will be fully sufficient for a column of so small a perpendicular.

If the employment of 12 men for 4 hours be thought too much, this work may be done in 3 hours 20 minutes by 2 ordinary horses, the pumps being contrived upon the same* principle, and 3 pumps to be worked by a triple crank, the proportions as follow:

Diameter of the working barrels		1 foot
Length of the stroke		3 feet
	No.	
Lantern on the crank spindles	19	cogs at 4½ inches pitch
Face wheel for driving ditto	84	
Mean diameter of the horse-tract		21 feet

Austhorpe, 4th September, 1767. J. SMEATON.

RIVER TRENT.

The Report of John Smeaton, *Engineer, concerning the Water-Road proposed to be carried across the Valley of the River Trent from Muskham to Newark.*

The points relating to the road above mentioned, referred to my consideration by the trustees thereof, at a meeting on the 19th day of December, were as follow.

1st. The propriety of the choice of the ground for the new road.

2d. The proper height of the road in respect of the water-line at the extreme of high floods.

3d. The proper quantity of water-way for the necessary passage of the water across the said road in time of the said floods.

4th. The particular places where the arches ought to be situated, and the number and dimensions of the arches proper at each particular place.

5th. The best method of construction of the said arches, so that they may be done at as little expense as possible, consistent with their being effectual.

6th. The proper section of the road where it passes through the grounds to be ramparted.

These are the propositions as I understand them, being verbally delivered.

1st. I am of opinion, that the ground marked out in the plan for the track of the new road is very properly chosen, being in general over the highest grounds, and sufficiently straight; and I look upon it to be an advantage that the arches will be as much as possible together.

2d. I apprehend that, to prevent damage to the road by its being overtopped, it will be advisable to make up its crown or summit to the height of 1 foot above the

* That is, not to lift the water above four feet at low water, and no higher than to overcome the resistance from without, at all other times.

respective water-line at the extremes of floods; and the top of the road being convex about 6 inches, the sides of the road will then be about 6 inches above the said water-line, which height above the water-line will also be necessary on account of the settlement, even after finished, though consolidated in the best manner practicable while making.

In order to ascertain the respective heights of the road above the surface of the ground, a point at Newark Bridge was shewn me by Mr. HANDLEY, as that to which the highest floods were never known to rise, and which has not been touched these 30 years: from this point I took a level to a mark at Muskham Bridge, shewn me by a person of Muskham, as the point to which the said floods arose; from whence it appears, that at a medium of two operations the flood-mark is lower at Muskham Bridge than that at Newark Bridge by 17 inches; and, though this medium differed 5 inches from the extremes (which difference of the two operations was the result of carrying the level 3 miles), yet, it is probable, it is very near the truth, as it differs but $1\frac{1}{2}$ inch from the level put down upon Mr. WILKINSON's plan in the middle of Lord MIDDLETON's lands, between Nos. 18 and 19, near Muskham Bridge. The level of the high-water mark upon the bridge itself, was shewn me by a different person from him that shewed the high-water mark to Mr. WILKINSON—therefore, they probably are not the same; and I have reason to believe that, from that part of the bridge having been repaired since the great flood above mentioned, the point shewn me was at least 6 inches lower than the real height of the great flood referred to, so that the fall of the water's surface from Newark to Muskham Bridge, will be reduced to about 11 inches. I have driven piquets near the course of the proposed road, between the two bridges, to the places of which the numbers in red refer upon the plan; and having given, by a section of the tract of ground, the respective depressions of the said piquet-heads below the water-line, upon the supposition of 11 inches' fall of the water's surface between the two bridges, this will be a sufficient guide for the laying out and forming the road.

3d. The proper quantity of water-way cannot, as it seems to me, be determined upon any fixed principles, because it is very difficult, if not impossible, to determine exactly what proportion of water in great floods runs over the surface to that which runs through the two bridges; all that can be done, therefore, is to make the best estimation we can, rather erring by allowing *too much*.

It happened somewhat luckily on this head, that I passed between the two bridges in a boat at the very highest of the great flood which happened on the melting of the snow in February 1766. I then remarked the height of the flood by a fixed mark, to which on this occasion I referred, and found that the surface of the water was then within $6\frac{1}{2}$ inches of the height that was now shewn me at Muskham Bridge as the highest of all. I also then took particular notice of the quantity of water flowing through the rails, gates, and void spaces in the hedges, and, considering the great depth of the river in its own channel, and the great obstructions the flood waters met with in passing the hedges from wreck, &c. deposited therein, I cannot, in my own mind, suppose that the whole water passing over the surface of the lands could equal that which passed through Muskham Bridge alone; but, that we may err on the safe side, let us consider the capacity of both bridges. Having, on the present occasion, taken dimensions of the water-ways of both bridges, and compared them with the length of the arching that will be equivalent thereto, upon a supposition that the flood arches upon an extreme flood carry a depth of water upon their floors of 6 feet at a medium, I find them as follow:

	Yards running.
Muskham Bridge equal to flood bridging	154
Newark ditto	99
Equivalent of both bridges in flood bridging	253

In order to check the above, I took an estimatory account of the whole openings in the line of the hedge on one side the present road through which all the flood waters must pass that run over the surface of the lands, and make them amount to an equivalent of flood bridging of 333 yards.

Now, the mean of the two determinations will be 293 yards, but, for a round number, let us say 300 yards, which is near $\frac{1}{9}$ more than the sum of the capacities of both bridges: now, this quantity, properly disposed of, will, in my opinion, be amply sufficient for discharging the flood waters, without the least danger or detriment of either the lands above the road, or to the road itself; and if the expense should make it needful, I am of opinion that the quantity above mentioned may be retrenched.

4th. The next article is the proper disposition of the arching above mentioned; and on viewing the face and levels of the country, it appears that the places where the flood-bridges now are, viz. at Crankley, and the three bridges, are the principal outlets for the flood waters. This experience has taught our forefathers, as is manifested by their placing bridges in those places; it follows, therefore, that those natural hollows, which lead the waters to those points, will be the properest places for the new flood-bridges, at the same time disposing of some arches or tunnels quite through the whole, to prevent any water remaining pent between the hedges in any particular place.

The arches I would recommend are of 12 feet wide, and 6 feet from the floor to the springer; they may be nearly all alike, except that in such places as will admit thereof, the floors may be laid lower, and the piers raised higher above the foundation than before specified, in order that one with another they may be of 6 feet depth of water; for lesser communications, I would propose tunnels of 5 feet width, covered by semicircular arches, the depth from the crown to the floor to be 6 feet, and the crown of the arch on the under side to be 2 feet 6 inches under the crown or summit of the road. According to these dimensions, three of these tunnels will be equivalent to one of the arches.

The places of the arches and tunnels as follow:

	Arches.	Tunnels.	Extent in clear water-way. Yards.	Feet.
In the low ground between the north end of Newark Bridge, and the higher grounds opposite the warehouse	9	0	36	0
In Mr. Ridgell's close	2	2	2	2
In Thomas Wood's ditto	0	1	1	1
In James Hanker's	0	2	2	2
Cross the valley at the three bridges	24	0	96	0
The further hollow in Mr. Stevenson's close, where the piquet, No. 8, is placed	0	3	4	0
In the drivers, where the piquet, No. 12, is placed	0	1	1	1
In the great hollow from the drivers to Langdale, crossing the water-course that leads to Crankley Bridge	24	0	96	0
In the low slade in the rector of Kelham's ground at No. 16	6	0	24	0
In the crossing of the old road	3	0	12	0
In Lord Middleton's land, near the south end of Muskham Bridge	3	0	12	0
Between Muskham Bridge and the high land at the north end thereof	3	0	12	0
	72	9	300	0

The above is the best disposition I can form for the placing of the water-ways from my own observations and the information I have had; but as the going away of the present snow may probably furnish a good opportunity of making observations upon the currency, it would not be improper to appoint a discreet person for that purpose. I am of opinion, however, that if the arches in those two places, which are laid out for 24 arches each, were reduced to 21, the water-way would be very ample.

5th. With respect to the construction of the arches, having explained myself by a design, I have the less to say thereon: it is necessary, however, to observe that, respecting the foundations, I have supposed it a firm gravel or clay, at the depth to which it will be necessary to excavate; but where it proves a soft clay, loose gravel, or sand, or still softer matter, it will be necessary to pile under the piers. In ordinary cases, piles from 5 to 8 feet long, and from 6 to 8 inches diameter, driven about 2 or $2\frac{1}{2}$ feet distance, middle and middle, will suffice; but as nothing can be ascertained on this head, without trial of the individual spot of ground in question, and as the firmness of the ground will frequently vary one pier from its next neighbour, the quantity and size must be increased or diminished at the discretion of the surveyor.

Where piles are not used, I propose the first course of bricks to be set edgeways upwards, the length of the bricks crossing the base of the pier, the whole to be driven down with a paviour's rammer in the manner of a pavement, and after that the interstices run full of grout or putty, or, if wet, to be filled with quick lime. If piles are used, bricks or half bricks to be drove down in the same manner in the interstices between the pile-heads, and then to begin the regular courses upon the paving and pile-heads promiscuously, being grouted as before. It is hardly necessary to say, that where a good foundation can be come at by going deeper, at a less expense than piling, it will be proper to do it.

As the arches are proposed to be but 12 feet wide, in order to avoid an unnecssary quantity of brick-work, I have supposed the shafts of the piers to be but $2\frac{1}{2}$ bricks thick, which, if built firm inside and out, will be very sufficient to carry the loads in such short spans; the arches themselves I have supposed to be no more than one brick thick, which I am also satisfied, if well done with good materials, will be quite sufficient: yet, as the supporting parts in the elevation have somewhat of a light appearance, if, to satisfy the eye, the trustees think it proper, half a brick may be added to the piers, and also half a brick to the arches within, which will make but little alteration in the design.

To save expense, I have supposed the whole to be of brick, the cap-stones for the terminating pillars of the parapet excepted, which are necessary to be of stone, on account of weight to keep on the brick caping; but if the expense can be admitted, it would give the whole a more substantial appearance to those who travel the road, to have the whole caping of stone. I suppose that the shoulder angles and springers of the piers, together with the capings, if of brick, to be made of their proper figure in moulds for that purpose.

To make all the piers thick enough to support all the adjacent arches *single*, without the counterbalance from the neighbouring arches, would bury a large quantity of materials; I have, therefore, adopted the thought of my ingenious friend Mr. MITCHELL, in making every third pier or every fifth strong enough for this purpose, that, in case of accident, the damage may not be progressive.

6th. In regard to the proper section of the road, it appears from the general section, that the flat ground from the point No. 4, to the three bridges, is the deepest flooded of any part that will be done by ramparting, and that the depth, at

a medium, below the water's surface is 4 feet: the mean height, therefore, of the crown of the road will be 5 feet; and for this height a section is drawn, shewing the excavations necessary on each side, in order to furnish matter to form it when consolidated; but if the bottoms of the canals on each side do not afford gravel for a cover, then the excavations may be of less width, on account of this part of the matter being brought from a distant place; but whatever be the height of the rampart, the same section will regulate it, by supposing the top of the road and angle of the slopes on each side to remain the same, and, therefore, the width only of the base to be variable, according to the quantity of matter required.

I suppose that in a few years, the ditches will silt and grass over so as to become pasture land, but as it will not only be unavoidable, but in some measure useful for the water, in time of great floods, to have a current along those ditches, it will be proper, as early as possible, to sow them with hay seeds, to prevent their sides from slipping, or from being galled by the current while they are new.

In order to prevent the surge, which in times of great floods will be raised by the action of the wind, from washing down the sides of the rampart before it can get firmly swarthed over, it will be necessary to set the slopes of the ramparts with sods, in the manner shewn in the section; and if the slope of the ditch next the rampart, as well as the opposite side where it faces the arches, was sodded also, it would be still better.

I have drawn the section of the road so to afford a breadth of 30 feet for the tread of the wheel, which I apprehend will be quite sufficient, especially where the rampart is raised high, as well as in the bridging; but in the high grounds, where the road is to be but little raised, it will not be necessary to be confined to this width.

Austhorpe, January 11, 1768. J. SMEATON.

GLASGOW BRIDGE.

Copy of a Report deliverved at Glasgow by Mr. Smeaton, in October, 1760, *from a Copy thereof received from Mr. Murdock in a Letter, dated April* 20, 1768.

"Report concerning the Situation of the intended New Bridge over the River Clyde, at Glasgow."

Having carefully examined the river at seven different places, viz. 1st, opposite Jamaica Street; 2d, at the middle of the island commonly called Ducat Green; 3d, in a line passing behind the Gorbal church; 4th, in a line agreeing with the street that runs before the Gorbal church; 5th, at the present bridge; 6th, at the slaughter-house, in a line with the new street; and 7th, at the Green of Glasgow, almost opposite to the gate leading from the bottom of the Salt Market, of which a particular account is contained in the paper annexed, from whence it appears to me that the situation of the present bridge is not the most eligible, for the following reasons: 1st, On account of the greatness of the length, which will increase the expense; 2d, by the street answering thereto on the Gorbal side being too narrow and embarrased, for the main avenue to a bridge of 30 feet wide: that street being not above 22 feet at a medium, and in several places not 18 feet; 3d, because it would not be safe to build a new bridge in the same place, except conformable with the old foundations, which would subject the new bridge to great irregularities; for as the present bridge appears to be founded upon the surface of a crust of gravel, covering

mud or sleech to an unknown depth, were the new foundation upon the interstices, and the old ones removed for the sake of giving a free passage to the water, as this crust is undoubtedly broke through in many places by piles, &c. it would be dangerous to remove them, lest, by giving advantage to the speats to gull away the ground from thence, a free passage is given to the mud to escape, and thereby to render the new pier liable to settlements. 4th. The disadvantage of wanting a bridge during the time of building a new one, or the charge of a temporary bridge balanced against the small value of the old materials, are too obvious to need insisting upon. 2d. The position agreeing with the front of the Gorbal church is not the most eligible, on account of the great length between the top of the bank on each side, so that it would require the extent of the bridge to be greater than its present situation; and as the north end would abut upon the workhouse dyke, would be too near, and too confined, without an opportunity of forming any new street in any good direction from thence, nor is the avenue from the south abutment free from objections, being but 27 feet in the widest part, and not above 19 opposite the church wall, which would require to be removed, and some private property purchased; nor is the cross street leading to the turnpike less exceptionable.

3d. The position agreeing with a line passing behind the Gorbal church, will clear the south abutment of all incumbrances, and mend the north, in regard to the practicability of making an opening into the green beyond the row of trees called the Old Green; but till that is done will be as much confined as the former, nor will this situation admit of any street in any good direction into the town, without passing through gardens and private properties; add to this, that here the bridge will be required the longest of all, the distance from the tops of the banks being upwards of 600 feet.

4th. To the position agreeing with Jamaica Street, are the following objections: the bottom is worst of all, and the water deepest, nor does the line of this street produced cut the stream at right angles, which is a disadvantage that ought always to be avoided, if possible; but without insisting on any objection to this situation on account of its being too near, and too much confining and embarrassing the present wharf or landing-place, or on account of its being too far removed from the present bulk of inhabitants, the foundation is a matter of consequence, for though the mud or sleech that lies under the bed of gravel is much of the same consistence as above (if any thing more soft), and may be made capable, by proper care and caution, of bearing the superstruction of a bridge; yet as the upper crust is considerably thinner, and less compact than above, it is justly to be apprehended that when the channel comes to be contracted by the piers, the increase of velocity of the water, in time of speats, may take away the bed of gravel between the piers, and by laying the mud exposed to the action of the water, may produce fatal consequences upon the adjoining piers; and this cannot be prevented but by a considerable addition of expense in the original construction, in piling, setting, and framing the whole of the spaces between the piers.

5th. At the slaughter-house, in a line with the new street, the river is of a moderate width, the running sand below the gravel lies the closest I ever met with at that depth; yet as the upper stratum of gravel is but loose, and the under crust very thin, this foundation is not without suspicion on account of the speats, nor does the line of the new street make a right angle with the stream of the river; so that after pulling down several houses in order to open an avenue thereto, the direction of the bridge cannot properly stand in a continued line with the street; the avenue on the south side will also be embarrassed in passing the Gorbals, for after pulling

down some houses to make an avenue answerable to the cross street leading to the turnpike on Paisley road, that street itself is in many places not more than 16 or 17 feet wide.

6th. The foundation at the green at Glasgow, opposite the gate leading from the Salt Market, is much the same as at the slaughter-house; the objection with respect to a passage through the Gorbals the same; the avenue from the bottom of the Salt Market might be somewhat enlarged, by removing the garden-wall, but the clear between the houses in the narrowest place is not more than 25½ feet.

7th. It now remains, that we examine the position at or near the middle of the Ducat Green; the width of the river between water and water is least of all, being at the boiler 345 feet, and from the top of the bank on the south side, to the top of the high ground on the island, 495 feet; from that point measuring across the Green, to the middle of the road down the avenue of trees, is 180 feet; from the top of the bank on the south side, to the Paisley road, in a direct line through the arable ground, 600 feet, which, allowing the breadth of the road to be 40 feet, will scarcely amount to half an acre Scots: in this position the new bridge will be about 900 feet distant from the present bridge, unembarrassed at either end, and capable of joining a new street that might hereafter be made across the Old Green, which may be made in a right line upon an arable close, and join the Troangate Street near to Mr. BUCHANAN's house, without interfering with any present buildings or gardens. The obliquity of the stream of the Clyde with the line will, indeed, occasion the position of the bridge not to be in the same line, but the obliquity will not be such as to occasion any material inconvenience with respect to the useful part. The foundation at this place, though not perfectly the best, is yet as good at bottom as any, and the bed of gravel as thick, and, in general, as compact as any, but the upper crust for about 8 or 9 inches not quite so hard as at the ford opposite the Gorbal Church, and at the present bridge, but much more compact than it is lower down; however, to remove all objections on account of the ground, I would propose to make the sum of the openings of the new bridge equal to the span of the river in that place; and, consequently, as the velocity of the water in time of speats would not be increased, there is no reason for supposing, that the said gravel that now sustains their efforts, will not continue so to do; and this may be done two ways, 1st. by digging away so much of the south side of the Ducat Green next the river as shall be equal to the sum of the solids of the bridge, and with the earth to fill up the back drain; 2d. by setting the abutments a little within the land on each side, and to procure a further addition of free passage by widening and deepening the back drain, over which I would throw a single arch.

The former way would be the more eligible, on account of the convenience of passages to the bridge; the latter will in that respect be sufficient, and amply so whenever a new street is made: but I apprehend the latter would better answer the conveniences of trade; for the widening this back drain to 40 feet, so as to admit of two vessels abreast, will admit of a convenient wharf on both sides, and will have this further effect, that a great quantity of water coming down this back drain in time of speats, would cleanse the face of the present quay, which towards the upper end is almost choked up, arising from the main stream being chiefly on the south side.

It, therefore, seems to me, that this situation of a new bridge will, upon the whole, be attended with the least inconveniences, be executed at the least expense, suit the conveniences of the present inhabitants, and favour any improvements that may be made further.

GLASGOW, October 20, 1760. Signed, J. SMEATON.

Measures, Soundings, and Observations, made upon the River Clyde, relative to a Choice of a proper Place for the intended New Bridge at Glasgow, made the 13th, 15th, 16th, and 17th of October, 1760, by JOHN SMEATON.

	Span of the river water and water.	Slope to the top of the Bray. On the South.	On the North.	Sum.	Depth.		Qualities of the soil in the middle of the river to 10 feet deep.
	Feet.	Feet.	Feet.	Feet.	Ft.	In.	
1st. Opposite Jamaica Street...	384	54	50	488	3	6	3 feet of loose channel, below mud or sleech.
2d. At the upper boiler on the island	345	100	50	495	2	6	5 feet of good channel, below ditto.
3d. Behind the Gorbal church	348	150	150	648	1	6	4 feet of good channel, below ditto.
4th. Before the Gorbal church	389	68	133	590	1	6	1 foot of hard channel, 3 feet looser ditto, and mud below.
5th. At the present bridge ...	536	21½	28½	586	3	0	1 foot very hard channel, and below ditto.
6th. At the slaughter-house...	360				2	0	3 feet loose channel, 1 foot hard ditto, below a running sand.
7th. At the Green of Glasgow	370				2	0	Ditto.

N.B. The general height of the bank on the south side is 13 feet above low water; the height on the north side, about 9 feet; there being then about 2 feet water upon the hirst.

WHITEHAVEN HARBOUR.

The Report of JOHN SMEATON, *Engineer, upon a View of the Harbour of Whitehaven.*

HAVING carefully viewed the harbour of Whitehaven upon the 7th and 8th of April, 1768, I am of opinion as follows.

That in case the expense and length of time attending such a work would permit its execution, that the noblest and best scheme would be to carry out a north pier, and to lengthen the new pier, till the heads of the two piers should be within a competent distance (suppose 200 feet) of each other; but, as I apprehend it would be many years before much relief could be procured to the trade by so extensive a work, the most ready way of enlarging the harbour would be by extending the old pier by some additional works, the particulars of which it will require leisure to judge of: but I am clearly of opinion, that if, during the coming summer, the old pier can be lengthened 30 yards, and turned a little more outward than the present direction, it will perfectly agree with every just idea of what is to follow, and that the prolongation aforesaid should be the first work done; and if, during this time, a correct plan of the harbour, piers, and appurtenances, together with the coast as far as Redness Point, is prepared to be laid before me, I shall then be in a condition to judge more accurately of what is to follow.

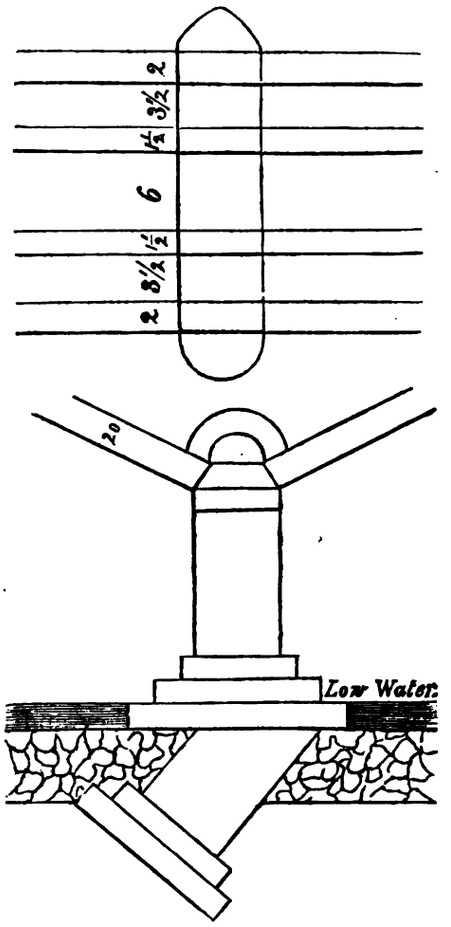
COCKERMOUTH, 8th April, 1768.

DUMBARTON BRIDGE.

The Report of JOHN SMEATON, *Engineer, upon the rebuilding the sunken Pier of Dumbarton Bridge.*

HAVING viewed and examined the sunken pier of the bridge of Dumbarton, and the nature of the ground upon which it stands, and finding that it is a soft mud to a depth unknown, it being tried to the depth of 46 feet below low-water mark, I do not know of any certain method of founding in such a situation; but, considering the very great difficulty and expense that will probably attend the taking up the present work to the bottom, being about 17 feet below low-water mark, and the great uncertainty of better success, if that could be done, I am of opinion that the best probable chance of success is to found a new pier upon the ruins of the old, and to make the superstructure as light as possible, the particular methods of doing which I have pointed out to Mr. JOHN BROWN, mason of the said bridge; and as the other piers and arches seem to stand firm, I think in the above way there is so far a reasonable prospect of success as to deserve to be attempted.

DUMBARTON, May 31, 1768. J. SMEATON.



LEWES LAUGHTON LEVEL.

The Report of JOHN SMEATON, Engineer, concerning the Drainage of Lewes Laughton Level, in the County of Sussex.

HAVING carefully viewed and examined the state of this level, upon the 17th, 18th, 19th, and 20th days of June, 1767, I found its condition as follows:

The preceding part of the season having proved wet, the level meadows called Brooks, lying upon the river Ouse, were, in general, under water from Land Port, above Lewes, to White Wall, below Rodmill. I observed that the surface of the water in the brooks of Southover, Itford, Pool Bar, Shine, and Rodmill, was nearly upon one common level, which several tracts of ground, for the ease of expression, I beg leave to call by the general name of the West Level: that there was but an inconsiderable fall of the surface of the water from the west level into the river, when the tide was down, and was some inches below the surface of the river when the tide was in; the same observation equally applied itself to Ranscombe. That the artificial banks or walls contiguous to the river bordering on both these levels, were low, and in very bad condition, so that, if the river was to swell 6 inches higher than it then was, the two levels and river would have one common surface. I observed, at the same time, that the lands below White Wall, from the south-east downwards, on the west side, and those of Tarring on the east, were in general dry, and in a tolerable state of drainage, which preferable condition thereof was undoubtedly owing to these three causes: the land itself is considerably higher; the banks made up higher, and in better repair; and their out-fall sluices fixed lower upon the river, which, in consequence, affords them a better fall.

It was observable during my stay, the tides being then in a mean state betwixt spring and neap, and the river pretty full of water, that the tides were scarcely sensible at Lewes Bridge, and but a few inches rise and fall at the mouth of the river Glynd; while, at the sheep-wash above Piddinghoe, the tides rose and fell 5 feet, and not above half a mile below, at the head of the Broad Salts, the rise and fall was near 8 feet; the greatest part of the whole fall lying betwixt the last-mentioned place and White Wall, a space not above $2\frac{1}{2}$ miles, according to the course of the river, and which includes at least $\frac{7}{8}$ of the whole fall, from Lewes Bridge to the head of the Broad Salts, which is a length of near 7 miles. This great declivity in the river from White Wall to the Broad Salts is doubtless owing to a series of shoals lying in that space, the principal of which is Piddinghoe, which alone occasions a fall of 3 feet, and which, as well as the narrowness and winding course of the river, altogether occasion the holding up the water in the river above White Wall, and which, in consequence, oppresses the levels lying thereupon, and still the more in proportion as their natural surfaces lie 2 feet at an average lower than the grounds below White Wall.

From the head of the Broad Salts downwards, the river is more spacious and open, and wherein the tides have full liberty to flow and reflow, and may be considered as an open tide's way. The declivity of the surface at low water is very gentle, till we come near the harbour's mouth of Newhaven, where the river Ouse falls into the sea, and where the water is held up by a bank of shingle, thrown in by the great seas and tides, and in part washed out again by the united force of the freshes and reflux of the tides, and which finds a balance betwixt these contrary powers, being somewhat variable according as one or the other happens to have the prevalence. From the surface of the water above this bank or bar, that is, from the

surface of the water in the pool where the ships lie, called Sleeper's Pool, I found a fall of 6½ feet to the low-water mark at sea, which, at spring-tides, is still greater.

The state of the brooks above, or north of Lewes Bridge, and which, for the sake of a general name, I beg leave to call the North Level, was as follows: they were almost entirely under water, as high up as Land Port; from thence, up as high as Iron Hole, they were in part under water; but, in general, where no water upon the surface, low and moist, and the appearance of being oppressed with water a too great length of time; but from thence to Barcombe mill, the meadows lie considerably higher, being, in general, 3 or 4 feet above the surface of the river, as it then was; however, as the whole course of the river through the North Level, from Barcombe mill to Lewes Bridge, has but an inconsiderable fall, is very crooked and winding, and in some places obstructed with shallows, the upper as well as the lower part of this level must be subject to be flooded on moderate down-falls of rain.

With respect to the brooks upon the river Glynd, eastward of Ranscombe, they appeared to be, in general, above water, but yet subject to too great a continuance of stagnant water upon them, partly from want of a sufficient fall in the river Glynd, and partly from crookedness and obstructions therein; however, as they appeared, in general, so much higher, that by whatever means the drainage of Ranscombe would be effected, must necessarily furnish the means of draining those brooks, I was less solicitous about the exact state of particulars.

It appears, moreover, from trying the different depths of the water in the different brooks, that the deepest under water were Ranscombe on the east side, and the S.E. part of Itford and part of Rodmill brooks in the west level, the general surface of those low parts being then about 3 feet under water.

From this general view of the state of the level, it would seem, that, if the obstructions arising from the several shallows, from the narrowness and crookedness of the river, between the mouth of the river Glynd and the top of the Broad Salts, were removed, which have been described to be the cause of the holding up of the river at and above the aforesaid limits, that the consequence would be a general drainage of all the levels; and it is certain, if these things were done, that this alone would be a great help to the whole of the grounds in question; but yet, as the taking away these obstructions would, in consequence, let the tides flow in with more rapidity, the natural declivity of the river being small, there would be scarcely time for the tide and fresh water to evacuate itself, before another tide would return, and thereby prevent its ever running so low as to admit of a complete drainage of the adjacent levels.

Towards an effectual drainage of these levels, two methods offer themselves; one is to straighten the river, and remove all obstructions as before described, and furthermore, to prevent the tides from having the effect above mentioned, to place a large out-fall sluice at its entrance into the open tide's way, with gates to shut out the tides from flowing up the river, and of sufficient dimensions to discharge the fresh waters at their greatest extreme; and, lastly, to embank Ranscombe and the west level against the overflow of the land floods, so as to convey the flood waters directly to sea, placing sufficient sluices upon their respective out-falls into the river, so as to shut out the land-floods, and give an opportunity of drainage when these floods are run off, which they will easily do, when not suffered to spread upon the adjacent levels; and, indeed, without embanking those levels as aforesaid, every method of drainage will be no more than a palliative help.

The second method supposes the river to remain in its present course, or without great alteration, to embank the lands to be drained against all extremes of floods,

and to convey their internal down-fall waters by a separate canal or sewer to the open tide's way, with a sluice upon the out-fall of the said canal, to prevent the reflux of the tides.

Each of these methods have their particular advantages: the first seems better adapted to give all the succour possible to all the country dependent on this out-fall; the second is more particularly adapted to the drainage of Ranscombe and the west level, the north and east levels being less advantageously situated by nature for drainage this way, as will more particularly appear from a further description and estimates that will follow of each method.

From an accurate level, taken the 18th and 19th of June last, it appears as follows:

	Feet	In.
Rise from low water to the head of Broad Salts, to the surface of the water in the west level..	6	5
The river being then charged with fresh water, the low-water surface at Broad Salts was said to be 2 feet, at least 18 inches above its low-water height in dry seasons, but taking it at ..	1	0
Rise from low water at the Broad Salts in dry seasons to the surface of the water in the west level	7	5
The mean depth of water in the low parts of the west level and of Ranscombe (subtract)	3	0
Rise from low water in dry seasons at the head of the Broad Salts, to the mean surface of the low parts of the west level and Ranscombe.....	4	5
Now in order to produce a complete drainage of those low grounds, it will be necessary to reduce the surface of the water, below the surface of the ground	2	0
There will then remain	2	5

It, therefore, appears that the water may, in dry seasons, be retained in the river 2 feet 5 inches above low water in the tide's way, and yet the surface reduced full 5 feet below the height it was in June 1767; and, as the deepest parts of the pool in Ranscombe (which is deepest of all) sounded only 4 feet 6 inches, it follows that the water may be reduced in the drains 6 inches below the bottom of the pool in Ranscombe.

In regard to the 2 feet 5 inches of water retained in the river above low water, it will be useful for navigation in dry seasons; and in small freshes, by affording so much fall, will thereby give the river a better current to sea, without overcharging the drains. In larger freshes, and great downfalls, the river's water will be prevented from over-riding the drains by their respective sluices, and the water will quickly discharge itself to sea, on account of its being confined between the banks, which are proposed to be made to prevent the rivers from overflowing the adjacent levels, as they do at present.

To effect these purposes, I would propose a new cut or river to be made across a corner of Tarring Tenantry, by which means Piddinghoe shoal will be avoided; a sluice is to be placed at the tail of this cut of three passages, 2 of 13 and 1 of 14, containing in the whole 40 feet clear water-way; the latter passage to be furnished with a double pair of pointing doors to seaward, and ditto to landward, for the sake of navigation; the other passages each to be furnished with a single pair of pointing doors to seaward, to shut out the tides, and a single pair to landward, to retain the fresh waters at a given height in dry seasons.

A dam to be put across the river at Piddinghoe sheep-wash, so as to shut out the tides, and to prevent the floods from passing that way after the aforesaid works are erected.*

* It is to be observed, however, that if there should happen to be any solid objection to putting a dam across the river at Piddinghoe sheep-wash, that the same purpose may be effected by putting sluices instead of a dam at the sheep-wash, in which case there will need no more than the 14-foot passage for the joint purposes of navigation and drainage upon the new cut proposed across Tarring brooks.

In order to avoid a crooked part of the river in passing by Itford and Stockhouse, containing a number of shoals, I propose to cut a new river from Stockferry to the turn below the White Wall, of the same dimensions as the former.

All the other shoals I propose to deepen, so as not only to lower the surface of the water at Lewes Bridge from 4 to 5 feet, but, also, to make full 3 feet 3 inches water over the shallows in the driest seasons, which will be a great improvement to the navigation, as vessels will not be stopped by neap-tides in dry seasons, nor obliged at any time to wait for the tides betwixt the sea-sluice and Lewes.

These works being effected, all the levels in question will be in a capacity of drainage, so that, each performing the particular works that relate to themselves, the whole will be in a condition of improvement.

As the west level and Ranscombe lie considerably lower than the rest, it is impossible they should be in a good state of drainage without being embanked against the freshes and floods of the rivers Ouse and Glynd; but instead of setting the banks close upon the river, I would, in the general, leave a space of 50 feet between the bank and the river, however varying this quantity, so that without following the sudden turns of the river, the bank may be reduced in length; observing, that where the bank is near the river on one side, it be put further off on the other, still forming an open space to give room for the passage of the floods in wet seasons.

According to this method, there will still be a necessity of sluices for the particular drainage of each tract of embanked land, to shut against the river in time of floods. Those already constructed might have answered the purpose had their thresholds been laid low enough, but as the thresholds of Shine and Ranscombe sluices, which lie the lowest, are, at a medium, but about 2 feet below the mean surface of the lowest lands respectively, they are insufficient for an effectual drainage, because before the water can come down to its proper pitch of level for drainage, its thickness over the thresholds will be so much diminished, as not to afford the water a sufficient passage. I, therefore, recommend a new sluice of brick for the west level, to be placed down as low as the White Wall, and another for Ranscombe, near the mouth of the river Glynd, their thresholds to be laid 2 feet lower than those of the sluices above-mentioned respectively.

In regard to the internal drains, what will be wanted further will be in the west level, one to join the sluice at Kingstone sewer, which sewer, when properly scoured out, will drain the western parts of the level; and those parts lying near the river, as far north as Cockshutt, will be drained by the back drain, which will, of course, be formed by taking the matter for embanking. In Ranscombe a new drain must be made, or the old ones scoured out from the sluice to the pool; but the back drain of the bank will be an effectual drainage for all the parts of the level near the river.

This is the whole, therefore, that can be expected to be done at a joint expense in these two levels; the division and other drains are to be made by the respective proprietors, at their particular expenses, and which I don't consider as any part of the object of this report.

At the time of my view the river had but an inconsiderable fall from Lewes Bridge to the mouth of the river Glynd, so that when the shallows are removed, the water in the river, as already mentioned, will, in its ordinary state, be reduced 4 feet at Lewes Bridge below what I found it,* and sometimes near 5, so that in the Lewes brooks above Cockshutt, the ordinary surface of the water in the river will be about

* The water under Lewes Bridge, when the levels were taken, was 3 feet 8¼ inches below the top of the aisler course of the S.E. wing of the bridge.

3 feet below the surface of the land; and in the brooks north of Lewes Bridge, from 3½ to 4 feet and upwards; so that, taking away some shoals above bridge to facilitate the passage of the water, I look upon all these brooks as in a state of drainage, liable, indeed, to be overflowed upon great downfalls of rain; but as, according to this construction, these downfalls will speedily run off, and leave the meadows dry, they will be liable to no other inconveniences than what water-side meadows generally are; what little banking or drainage will be further necessary for their security, I suppose to be left to the discretion and management of each particular proprietor.

The same reasoning will hold with respect to the brooks upon the Glynd, east of Ranscombe, for, the water being reduced from the surface, I found it full 5 feet perpendicular at the out-fall of the Glynd into Ouse; there will be little further to do, than to scour out the river Glynd, so as to take advantage of the falls so obtained: the scouring out the river Glynd I look upon as a work particular to the brooks east of Swale Bank; and what further banking and draining may be necessary, I, in like manner, suppose to be the work of the respective proprietors, and not the object of this scheme, which is to point out the general methods by which the whole will be put in a *capacity* of drainage, not to drain the lands, ready for the husbandman.

I have already shewn that the work of the drainage thus constituted will be advantageous to the navigation of the river for the barges, and an advantage for which, in my opinion, they ought to pay a toll towards the ease of the general undertaking: it now remains to shew that the constructions proposed will be no ways detrimental to the harbour of Newhaven; on the contrary, I propose to demonstrate, that it will be a considerable advantage, upon the principles of the first scheme now described, for as to the second it cannot be made a question.

I know it will be immediately apprehended, that the tides being stopped at Piddinghoe, will occasion a less influx of the tide at the mouth of the harbour; and as a less influx will produce a less reflux, the power will thereby be diminished by which the sand, shingle, &c., is driven out to sea, that is brought into the harbour's mouth by storms and hard gales of wind bearing strong upon the coast: but this reasoning, however plausible it may appear, and however true it may be in some cases, yet, in the present, it will not hold; but I must observe, that if admitted, the quantity in question is so small in proportion to the whole, that its effects can produce no sensible difference in the scour of the harbour; the quantity of tide-water, then, in question, will be only such as flows into and out of the river above Piddinghoe shallow; this, at the time I was there, amounted to a rise and fall of 5 feet, as already stated, at Piddinghoe sheep-wash; but at White Wall, not 2½ miles up the river, the rise and fall were not above a foot, and at Lewes Bridge scarcely sensible, so that the greatest part of the influent water was contained in about 2½ miles of river, at the mean depth of 3 feet, and at a mean width not exceeding 30 or 35 feet,* which will evidently bear but a small proportion to the water contained in the river from the pier of Newhaven to Piddinghoe, where the mean rise and fall was three as times as great, the mean breadth more than double, nearer three times, and the length above three miles, besides the water flowing a considerable breadth near a mile up the old harbour, as far as the tide-mill: this would be the proportion, supposing all the tide's water above Piddinghoe to be quite lost; but the real quantity of reflux lost by the river above Piddinghoe, will be greatly diminished, below what

* I am sensible that, in dry seasons, when there is less land water in the river, the rise and fall of the tides will be greater, and be sensible further up the country; but as the efflux will be less for want of the land water, the effect in scouring must be less than at the time above stated.

is above stated, when it is known that the tide at Piddinghoe did not rise so high by above a foot (I made it 1 foot 3 inches) as it did at the pier-head the same tide; from whence it follows, that the tide having room to spread and spend itself faster than it can be supplied at the mouth, the ponds within are never filled within 6 or 7 inches at a medium so high as they would be if they were so much less as to have time to fill to the level of the tide at sea; we have, therefore, grounds to say, that if the tide was prevented from spending itself so far up the river, it would occasion the remaining space to fill to a higher level, and thereby take in a quantity, upon the whole, nearly as large as if suffered to flow further; and that this reasoning is true, further appears from this fact, that in spring-tides the water gets so far up the river, that, not having tide to get back again, the same tide fills the river above White Wall fuller and fuller, which is not evacuated but by the neaps that succeed.*

From what has been said we may be assured, that the stop of the tides at Piddinghoe could be of no great consequence to the harbour, even upon a supposition that the tide-water there lodged *is useful* towards clearing the harbour's mouth, which I come now to shew that it is not, but, in the present case, detrimental.

When the wind is *in shore*, and brings a heavy sea upon the harbour's mouth, the shingle is thereby put in agitation; and, if a strong tide of flood happens during such violent agitation, the indraught of the tide brings in a quantity of shingle, and loads the entry of the harbour; and this effect will (*cæteris paribus*) be greatest when the indraught is strongest, that is, when there is the greatest tides, and the least fresh water in the river to oppose them; and this indraught will also be strongest when there is a narrow entry and a great space wherein the water may expand itself, for there the tides of flood will set in through the harbour's mouth the most rapidly. These circumstances concur in a strong degree in the present case, and, therefore, a diminution of their *expansion* must diminish the *rapidity of tide of flood*; at such a time when the river has no great currency downwards, the tides, as already observed, instead of returning wholly to sea, are spending themselves up the river to Lewes, which occasions a rapid influx and a languid efflux; the river is, therefore, at this time in no condition to evacuate the shingle so brought in; here it must lie till something happens to turn the balance the contrary way, and this is done by the land-floods joining with the tides, which promote a brisk reflow to sea. Now, at such times, the land-floods will at Piddinghoe *over-ride* the tides, and the sluice-doors will be open the whole time of tide; the sluice, therefore, will not, in any respect, impede the land-floods from getting to sea, and, by the embanking of the river, they will be brought down with greater rapidity, and thereby produce a scour superior to what it can obtain in the present state of things. Since, therefore, the rapidity of the tide of flood will be diminished, and the ebb-tide increased, at such times when alone they can be of use in scouring, the effect upon the clearing of the harbour's mouth must be beneficial.†

I come now to describe the second method of drainage, whereby the river will be left in its natural course; and whereby, if the drainage of the west level and Ranscombe were the only objects in view, the work would be done at the easiest expense, as will be more particularly seen by the estimates.

This consists of an entire embankment of the rivers against all extremes of floods, so far as the drainage is carried, thereby shutting the river entirely out; so that

* N.B. The high water before referred to was near 1 foot higher at Piddinghoe than it was at Lewes Bridge.

† By fixing doors proper for that intent, this sluice may be made useful for procuring artificial scours at low water in dry seasons.

instead of discharging the downfall waters into the river at the point opposite the respective tracts of ground, it is to be collected into one drain, and finally discharged into the open tide's way by means of a sluice, which, shutting out the tides, prevents at once the reversion of the water for the whole level. This sluice and drain will be far less in point of water-way than that before proposed, having nothing to convey to sea but the downfall water of the levels to be drained; whereas the other must be large enough to afford a sufficient passage to sea to the flood-waters of the whole river in the greatest extremes of floods. This second method is, in many cases, to be preferred, as it stands clear of all difficulties respecting the altering the current or navigation of the river, and is, in itself, *most perfect*; but, in the present case, the north and east levels are situated so disadvantageously, with respect to their communication with the general out-fall, that to accomplish the whole in this way will be more expensive than by the first method. But, to proceed:

I propose the outfall sluice to be nearly at the same place of the river as before proposed, and to be of 12-feet water-way; from hence a drain of 12-feet bottom to be carried through Tarring Tenantry, and, by means of a subterraneous tunnel, to cross the river Ouse in a proper point between Stock Ferry and Stockhouse, from thence to the low grounds of South Ease, and cross the White Wall to a point of division in Rodmill Tenantry, there to branch off in three directions: the N.W. branch to fall in with Kingston drain; the north branch to pass between the two Ries to bring down the cock-shot water, which will be useful for the cattle, and prevent its being particularly embanked; from thence through Lewes brooks below bridge, and under the river Ouse in a subterraneous tunnel, answerable to one of the old passages that cross the street east of Lewes Bridge; from thence through the Malling brooks, and again crossing the river into Lewes brooks above bridge, from thence upland port brooks, skirting the river with a bank and drain (without following the minute windings) as far as the drainage is wanted to be carried, which, on the west side, I have supposed to be as far up as the iron-hole; for the sake of the brooks east of the river another tunnel will be necessary to convey their drainage across the Ouse a little above Mr. KEMP's, and thence, skirting the river with bank and drain as on the east side, as far as the artificial drainages are wanted, which I have supposed to be the Carp-Hole or Horse-Shoe brook.

Returning now to the point of division, the N.E. branch is intended to cross the river Ouse by a subterraneous tunnel, and proceed directly to the pool in Ranscombe, from thence, proceeding eastward, to cross the boundary of Ranscombe, and after that skirting the river Glynd with a bank and drain on the north side till we are past the turnpike-road, and the brooks grow broad and open on the south side the river; from this point the drain is to be pursued on the north side, supposed to Edley, for draining the great hoof, &c. crossing the Glynd from the said point, by a subterraneous tunnel, and in like manner carrying a bank and drain on the south side; this will serve for a drainage of the Firle brooks, and what else on that side of the river may be further necessary.

The Beddingham, Asom, and Itford brooks are also to be drained by a subterraneous tunnel under the river Glynd, to communicate its drainage with Ranscombe.

The carrying the drainage through the South Ease and Tarring brooks may possibly be objected to, as bringing the waters upon them; but, as they lie higher than the rest, and the earth dug out of the drains forming, of course, a much more than sufficient barrier-bank, they cannot possibly receive any prejudice, but, on the contrary, will have their drainage rendered more effectual by draining into the new cuts proposed to pass through them.

AUSTHORPE, 27th July, 1768. J. SMEATON.

P.S. The general level, as taken the 18th and 19th of June, 1767, from the sea to Lewes Bridge, the latter being the moon's quarter-day, was as follows:—

	Ft.	In.
Rise from the sea (at a flowing water) to the pier head at Newhaven	4	0¾
From the pier head to Sleeper's Pool	1	8¼
From Sleeper's Pool to the top of the Broad Salts, below Piddinghoe, by estimation	0	10
From low water surface, at the top of the Broad Salts, to the water's surface in the west level near Shine sluice	6	5
Rise from the surface of the west level water to the surface of ditto, at Lewes Bridge, by estimation	0	4
	13	4

N.B. On comparing the high water mark at the pier-head at Newhaven, on the 17th, with the foregoing levels, it appears, that the high water at the pier-head was above the level of the surface of the water at Lewes Bridge, the same day, 2 feet 2 inches.

ESTIMATE

For Lewes Laughton Level, upon the Principles of the First Scheme.

GENERAL WORKS.

	£.	s.	d.
To a sea-sluice of 40 feet water-way, containing three passages, two of 13 feet each, with pointing doors to seaward to keep out the tides, and ditto to the land, for holding up water for the navigation in dry seasons, and one passage of 14 feet, to be furnished with a double pair of gates pointing to seaward, in order not only to keep out the tides, but to form a navigable lock to let the vessels pass at all times; to be built with brick, with stone quoins and facings, the thresholds to be laid 2 feet below low water mark, in that part of the river opposite the sluice	4000	0	0
To cutting a new river opposite Piddinghoe, to be 27 feet bottom, and sloped in proportion of 3 to 5 (that is 3 perpendicular to 5 horizontally), and being 9½ feet deep, will be 59 feet at top, and which, for 4 furlongs 3 chains' length, will contain 42,948 yards, at 5*d.* including drainage	894	15	0
To 7$\frac{68}{100}$ acres of land for the cut and cover, the cover being supposed at half value, is reckoned at half quantity; the value per acre I do not pretend to judge of, but if, for the sake of estimation, it be reckoned at 40*l.* an acre, this will come to	307	4	0
To a new cut from the turn of the river below White Wall, to the turn of the river above Stock Ferry, being of the same dimensions as the other, and 4·6 furlongs in length, will, at the same price, come to	957	3	9
To 8$\frac{28}{100}$ acres of land, at the same price, cut and cover	328	16	0
In order to prevent the necessity of letting in the tides, for the sake of the navigation in dry seasons, and also to give the water a more free passage in its lowest state, it will be necessary to deepen the following shoals, viz. Dean shallow, Sound shallow, Bramble Bush ditto, Snow ditto, Cliff ditto, and Tapsall ditto, these at 100*l.* each, will come to	600	0	0
General works	7087	18	9

Particular Works for the Levels West of the Ouse, below Lewes Bridge, and on both Sides above, on North of ditto.

To making new banks on the west side of the river, from the head of the new cut below White Wall, to the high land at Southover, being in length 28 furlongs, to be at a medium 24 feet seat, 6 feet top, and 6 feet high, the matter being taken out on one side, so as to form a back drain, at 3*d.*	770	0	0
Carried over	770	0	0

	£.	s.	d.
Brought over	770	0	0
To land to be converted into a drain, in order to make the bank (the land being low, I reckon no spoil of land by the cover of the bank), this, for 28 furlongs' length, will be 10·1 acres, which, if valued at 15*l.* per acre, will come to	151	10	0
To making a new sluice, of 6 feet clear water-way, on the north side of White Wall, the threshold to be laid two feet lower than Shine sluice, to be built of brick, with stone facings	300	0	0
To making a drain from the new sluice to join Kingston sewer, to have a 6-feet bottom, slopes as 3 to 4, and, at a medium, 5 feet deep, this, for 7½ furlongs, at 2½*d.* per yard including drainage, is	120	6	8
To land to be cut for the said drain, the land being low, I reckon no damage for cover $2\frac{2}{10}$ acres, which, if reckoned at 15*l.* per acre	33	0	0
To taking out four shallows above Lewes, that obstruct the regular course of the current, viz. the washing-place opposite St. John's Bell Shallow, above Mr. KEMP's, Stoneham sheepwash, and Hansey Flats, at 50*l.* each	200	0	0
Particular expense of the west and north levels	1574	16	3

Particular Works for Ranscombe Level, and Level on the Glynde, on the East of the Ouse.

To embanking Ranscombe, from the high lands at Walker's Hole, 10 furlongs, and up the river Glynde to Swale Bank, 9 furlongs, of the same dimensions and price as before	522	10	0
To $6\frac{84}{100}$ acres of land, to be converted into a drain to make the bank, at 15*l.*	102	12	0
To a new sluice at Ranscombe of 4 feet clear water-way, the threshold to be laid 2 feet lower than the threshold of the present sluice, to be built as the former	200	0	0
To embanking of Ranscombe as before proposed, supposes the matter to be taken at the greatest convenience all round; but, for the more perfect drainage of the brooks upon the Glynde, above Swale Bank, it will be necessary to take out a part of the earth from the river Glynde, in order to dyke it out; the extra expense, therefore, in dyking out the river Glynde, from its mouth to Swale Bank, and therewith in part making the bank alongside, so as to make it 1 foot deeper than the present threshold of Ranscombe sluice, may be set at	90	0	0
To dyking out and scouring the river Glynde, from Swale Bank to the west end of the Great Hoof, for procuring a general outfall to the eastern brooks, being in length 12 furlongs, that is 480 roods, at 10*s.*	240	0	0
Particular works for Ranscombe, and levels on the Glynde	1155	2	0

ABSTRACT.

General works	7087	18	9
Particular expense of the west and north levels	1574	16	3
Particular works for Ranscombe, and levels upon the Glynde	1155	2	0
	9817	17	0
Upon the above we may allow 10 per cent for unforeseen accidents, and contingent works not brought to account in the above, together with utensils and supervisal	981	15	8
	10,799	12	8

SECOND ESTIMATE

For Lewes Laughton Level upon the Principles of the Second Scheme.

GENERAL WORKS.

To the sea-sluice at the tail of the main drain of 12 feet clear water-way, the threshold to be laid 1 foot below low water mark, with pointing doors to seaward, and draw-gates to landward, for holding up water in dry seasons for the use of cattle, to be built with brick, with stone facings	1200	0	0
Carried over	1200	0	0

	£.	s.	d.
Brought over	1200	0	0
To the main drain, to be carried, as per plan, through Tarring Tenantry to White Wall, to have a 12-feet bottom, slopes as 3 to 4, to be dug as deep as the sill of the sluice, that is, at a medium, 8½ feet deep, the length being 15 furlongs, at 4½*d.* per yard, including drainage	1361	5	0
To putting a subterraneous tunnel across the river Ouse, in the reach between Stock Ferry and Stockhouse, of 12 feet water-way	1000	0	0
To continuing the main drain from White Wall to the point of division, bottom and slopes as before, the depth being about 6 feet, and 5½ furlongs length, at 4*d.* including drainage	268	17	7
To purchase of lands from the outfall sluice to White Wall, cut and damage of cover, at 66 feet broad, and 15 furlongs length, will contain 15 acres, which, if estimated as before at 40*l.*, will come to	600	0	0
To purchase of lands for the cut from White Wall to the point of division (the land being low, I reckon no damage of cover), at 27 feet breadth, and 5½ furlongs length, make $2\frac{3}{10}$ acres, which, if valued at 15*l.* per acre, comes to	34	5	0
General works	4464	7	7

Estimate of Works to be done in the West Level.

To continuing the drain from the point of division, up to meet Kingston sewer, upon a 6-feet bottom; the batters 3 to 4, and, at a medium, 5 feet deep; this for 2·4 furlongs, at 2½*d.* per yard, including drainage, comes to	38	10	0
To land for the drain to join Kingston sewer, containing $\frac{35}{100}$ acres, at 15*l.*	5	5	0
To embanking the river Ouse from White Wall to the top of Lewes brooks below bridge, to be, at a medium, 24 feet seat, 6 feet top, and 6 feet high, at 3*d.* per yard; the forming a back drain included, will, for 30 furlongs, come to	825	0	0
To $10\frac{8}{10}$ acres of land, converted into a drain for forming the aforesaid bank, at 15*l.*	162	0	0
To cutting a new north sewer, from the point of division to its junction with the bank drain, to have a 6-feet bottom, batters as 3 to 4, and five feet mean depth, containing 11 furlongs in length; this, at 2½*d.* per yard, including drainage, comes to	176	9	2
To land for the above cut, no spoil of cover, containing $3\frac{82}{100}$ acres, at 15*l.* per acre	48	6	0
Particular charge of the west level	1255	10	2

Estimate for the north Brooks above Lewes Bridge.

To making a 5-feet tunnel across the river, at the head of Lewes brooks	600	0	0
To making a sewer of 6 feet bottom, with slopes as 3 to 4, and therewith forming a bank, by laying the earth on one side, at a medium, 5 feet deep, will make a bank 20 feet seat, 5 feet top, and 5 feet high; this, at 2½*d.* per yard, cutting and banking included, for 30 furlongs, from the river opposite the head of Lewes brooks, below bridge, to the iron hole at the head of Hansey farm	481	5	0
To land for the above sewer, containing $8\frac{8}{10}$ acres, at 15*l.* an acre, no spoil allowed for banks	132	0	0
To probable extra expenses in the cut passing the street east side of Lewes Bridge	250	0	0
To a 5-feet tunnel to pass the river, from Malling brooks to Lewes brooks, above bridge	500	0	0
To a 3-feet tunnel to pass the river above Mr. KEMP's, to communicate the drainage from the east side	400	0	0
To making a bank and sewer from the said tunnel on the east, to the Horse-Shoe brooks, of the same dimensions as the former, being 21 furlongs	336	17	6
To land for the above drain, $6\frac{15}{100}$ acres, at 15*l.*	92	5	0
North brooks	2792	7	6

Estimate for the Drainage of Ranscombe.

	£.	s.	d.
To cutting a main drain, from the point of division to Ranscombe pool, to have a 6-feet bottom, batters as 3 to 4, and at a medium of 5 feet deep, the length being 8½ furlongs, at 2½*d.* per yard	136	7	1
To land for the above cut, containing $2\frac{49}{100}$ acres, at 15*l.*	37	7	0
To making a 6-feet tunnel across the river Ouse	800	0	0
To embanking Ranscombe, from the high lands at Walker's Hole, by the river Ouse, to the Glynde, and up the river Glynde to Swale Bank, to have a 24-feet seat, 6 feet top, and 6 feet high; this, for 19 furlongs, at 3*d.* per yard, back drains included, comes to	522	10	0
To 6·84 acres of land, occupied by the drain from whence the bank is to be taken, at 15*l.*	102	12	0
Particular charge for Ranscombe	1598	16	1

Charge of Draining the east Brooks, or Brooks east of Ranscombe, as also those of Beddingham, Asem, and Itford.

To cutting a drain from Ranscombe pool to the east extremity of Ranscombe, to have a 6-feet bottom, slopes as 3 to 4, and, at a medium, 5 feet deep; this, for 6 furlongs, at 2½*d.* per yard, will come to	96	5	0
To land for the above, $1\frac{76}{100}$ acres, at 15*l.*	26	8	0
To cutting a drain of 6 feet bottom, with slopes as 3 to 4, and therewith forming a bank against the river Glynde, by laying the earth on one side, at a medium, 5 feet deep, will make a bank of 20 feet seat, 5 feet top, and 5 feet high; this, for 18 furlongs from the head of Swale Bank, through the Great Hoof to Horse Brook, at 2½*d.* per yard, will come to	336	3	0
To land for the above drain, $5\frac{27}{100}$, at 15*l.*	79	0	0
To putting a 3-feet tunnel across the river Glynde below the Great Hoof, in order to communicate the drainage of Firle brooks with the former drain on the north side	150	0	0
To embanking the Firle brooks against the river Glynde, opposite the Great Hoof, and therewith forming a drain, supposed of the same dimensions as the north side; this, for 9 furlongs, will come to	144	7	6
To land for ditto, $2\frac{64}{100}$ acres, at 15*l.*	39	12	0
To putting a tunnel across the river Glynde, in order to drain Beddingham brooks, of 3 feet water-way	200	0	0
To embanking those brooks against the river Glynde, and thereby making a drain behind the bank, which is to have a 24-feet seat, 6 feet top, and 6 feet high; this, at 3*d.* per yard, for 7 furlongs, will come to	192	10	0
To land for the above drain, $2\frac{52}{100}$ acres, at 15*l.*	37	16	0
To embanking Asem and Itford brooks against the river Ouse, and thereby making a drain behind the bank to communicate with that of Beddingham, being in length 14 furlongs, which, being of dimensions and price as Beddingham, will come to	385	0	0
To land for the above drain, $5\frac{1}{100}$ acres, at 15*l.*	75	12	0
Particular charge of the brooks upon the Glynde, exclusive of Ranscombe	1762	13	6

Abstract of the Drainage of Lewes Laughton Level, by the second Method.

The general works for bringing the drainage to the point of division in the west level	4464	7	7
The particular charge of the works for the drainage of the west level	1255	10	2
Estimate for the north brooks above Lewes Bridge	2792	7	6
Estimate for the drainage of Ranscombe	1598	16	1
Charge of draining the brooks east of Ranscombe, as also those of Beddingham, Asem, and Itford	1762	13	6
Upon the above we may allow 10 per cent for unforeseen accidents and contingent works not brought to account in the above, together with utensils and supervisal	1187	7	6
	13,061	2	4

Austhorpe, July 27, 1768. J. SMEATON.

A SHIP'S PUMP.

Description of a Ship's Pump, designed by JOHN SMEATON, *Engineer.*

A PUMP of this construction was designed in the year 1765 by Mr. SMEATON, and executed from his directions by Messrs. HURREY and Co. at Howden Dock, upon the river Tyne, the latter end of the same year, which meeting with the approbation of the master of the ship on board which it was first fixed, who reported that it had actually saved the ship, some others have since been made nearly similar by the same company; but the superior expense has hitherto prevented so great a demand as might have been expected. In the present design, in which the whole has been carefully reconsidered, I have not rigidly adhered to the particularities of the first construction, but altered such smaller matters as convenience seemed to suggest.

Besides the advantages that were expected to accrue above the common form from better mechanism and proportion of the parts, the following was in view: the common ship's pump in general delivers its water upon the main deck, which, according to the largeness and construction of the ship, is 4, 5, and 6 feet above the load water line, at the same time that the load water line is not above from 14 to 18 feet above the ship's bottom; it therefore appears, that the ordinary pumps lift the water from $\frac{1}{3}$ to $\frac{1}{4}$ higher than the level at which the water might be delivered, and thereby require $\frac{1}{3}$ or $\frac{1}{4}$ more power to do the same work, or with the same power to do less work than they might do by $\frac{1}{3}$ or $\frac{1}{4}$, in case the water was delivered at or just above the water line for this purpose.

A A, boxes let in through the ship's side, and caulked just above the load water line.

B B are side pipes, jointed with the boxes, and with

C C, strong planks bolted against the sides of the pump, in order that the side-pipes may be got out and in without disturbance to the pump.

D D is a stand-pipe, to be carried up to the main deck, or as high as is thought necessary, that when the seas rise above the orifices, or the ship in distress, should be under her load water line, that the water may not revert and run into the ship: and here it is to be noted, that both boxes and pipes should be wholly under water, yet it will no ways interrupt the action of the pump; for whenever the water in the standing pipe rises above the level of the water without, the pressure of the column in the stand-pipe will cause it to make its way through the side-pipes; so that in this case no level will be lost, and though the pump is at rest, no water can revert down the pump, because there are the valves of both bucket and fixed box to prevent it.

The present design is adapted to be worked at the height of 22 feet by four men, who working at a moderate rate, so as to hold it an hour, will in that time deliver 20 tons. This is upon a supposition of raising the water to the usual height; but if, by the application of the maxims above described, this perpendicular is shortened to 16 or 17 feet, then will the same delivery nearly be made by three men, or proportionably more by four men, that is, as 17 : 22 :: 20 : 26 tons at 17 feet, but in this case, the distance of the centre of the lever or brake must be lengthened from 1 foot 6 inches to 1 foot 11 inches 3, and the barrel must be lengthened 4 inches.

According as the design is drawn, viz. for a perpendicular of 22 feet by four men, they are supposed to make no more than 25 strokes per minute, moving the pump-rod 13½ up and down at each stroke. This will be much better than to make shorter strokes and quicker, as they usually do; in this case their hands will move up and down about 4 feet 6 inches, and the same number of strokes, scope, and pressure at

the hand will be sufficient for the reduced perpendicular, but then the stroke of the pump-rod will be 17¼ inches.

With respect to the mechanism, I believe it will appear sufficiently plain by the designs, which are drawn true to a scale; but it may be necessary to remark, that the working-barrel is to be of brass, and very truly bored, the bucket and fixed box of the same construction as those used in the steam-engines, and the pump-rod is to be made of the bulk represented in the figures, not by way of strength, but by way of weight, that when the brake is lifted up, the pump-rod may readily descend by its own weight; and it is to be noted, that if the weight arising from the dimensions specified does not carry it down with sufficient readiness, that it is a sign the bucket is too hard leathered, or the valves too heavy.

It is to be observed, that the foot of the pump is to be let through the ceiling betwixt two of the floor timbers, and not to touch the bottom or outside planking within 2½ inches, and that the lower end be rounded trumpet fashion. I entirely object to the pump's standing upon its lower extremity, with holes bored to let in the water.

N.B. If the foot stands close to one or both timbers, there ought to be left 8 inches between the bottom and the planking.

In case the pump is made to the 22-feet height, the stand-pipe will then become unnecessary; and, therefore, to allow a proper length and weight to the pump-rod, it will be proper to let down the working barrel door and box lower down in the tree. The quantity must be assigned by the convenience of coming at the door; but the working-barrel had better not be above 16 or 17 feet above the bottom, if it can be avoided.

The four men are supposed to stand one on each side the middle stem of the brake, and one on each outside of the branches, and every quarter of an hour they will find an easement by changing hands, which is done by changing places.

This pump may be worked by six men, but not so as to produce a greater quantity in proportion to four; it may also by three, but then they must change every quarter of an hour.

It may be made also to work double, in which case eight men may be employed with advantage; but, as I imagine two independent pumps will be better adapted to ships' use, that if one be out of order, or happen an accident, the other may be serviceable, it is for this reason I have not given a design for a double pump.

I suppose it scarce needful to say, that it would be proper that a bit of the ceiling should be made to lift up near the pump's foot, that a man may occasionally get in his arm to clear away any chips, sand, dirt, or other matter that may happen to be drawn thither.

Austhorpe, 9th August, 1768. J. SMEATON.

CARRON FURNACE.

The Report of John Smeaton, Engineer, concerning the Improvements of the Blast at the Furnace at Carron, No. 4.

Having maturely considered the easiest and most effectual way of altering the blast No. 4, so as to perform its business equally with No. 1, I recommend the following alterations, yet, without a total change, which is not the present object; the company will be obliged to submit to its using more water than No. 1, though, in this respect, they will find it greatly improved beyond its present state.

I would advise that the water-wheel and the three cylinders, with their respective beams, remain as they now do, as also the frame that holds the crank, but to add a fourth cylinder abreast of the other three, on the outside, or furthest off from the water-wheel, as also a fourth beam abreast of the other; the fourth cylinder to be of the same size, and in all respects fitted up similar to the other three. On this occasion it will be necessary to cast a new crank with four necks, making right angles with one another, and at distances answerable to the four beams, and having the same sweep as at present. I am not perfectly clear whether there may be room enough between the present outmost cylinder and the wall to place the new one, but if not, the wall must be cut away to make room for it; with respect to the beam, it is no matter if it works very near the wall. Another couple, or frame, must be added for the crank like the present, and like the present the fourth neck may work in the air without an outward support. The receiver or air vessel will probably want recasting, to receive a fourth air-pipe from the fourth cylinder, unless the workmen can contrive to cut a hole into it, and by proper straps to confine the additional pipe thereto.

As I observed a great deal of friction in the rods passing the collars in the top of the cylinder, and yet lost a great deal of air, I mentioned last summer a method of leathering them, as well as those of the fire-engine, in a different way, whereby they would not only be rendered air-tight, but the friction in a great measure avoided; and, that this method may be properly and successfully applied, I inclose a drawing, which method I advise to be applied, not only to the new cylinder, but to the three old ones, which may be done by cutting off the present necks, and drilling holes for the bolts.

Description of the Collar of Leather to be applied to the Blowing-machine at Carron, No. 4.

A B represents a portion of the cylindrical rods that work through the collar of leather.

C D is a portion of the section of the great plate that covers the top of the cylinders.

E F is a section of a cylindrical piece of wood, having a cylindrical hole through the middle, through which the rod may slide freely, but with as little shake as possible, which is to be made of beech, crab-tree, yew, or some hard or tough wood that will wear well with iron.

abc abc shews the section of the leather by which the hole is made air-tight, and is like a hat with the top of the crown cut out.

GHIK GHIK is a section of a cylindrical box for holding the cylindrical piece of wood, with proper flanches, by which the box is screwed down to the cover C D, and by which the plate, of which L M is the section, is screwed down so as to hold fast.

N O is the section of a piece of leather for securing the joint betwixt the box and the cover.

It is obvious from the figure, that no part of the cylindrical rod is intended to touch the iron-work nor the leather N O, but that it is to be kept steady by the wooden cylinder, and the joint rendered air-tight by the pliable cylinder of leather *bc bc*, which, as well as the wood, are to be changed whenever they are found to fail.

The method of making those leathers is as follows:

P Q represents the section of a cylindrical iron ring, whose external diameter is

equal to that of the wood C D, and whose internal diameter is about $\frac{1}{4}$ of an inch larger than the diameter of the cylindrical iron rod A B.

R S is the section of a flat round piece of leather of about $\frac{1}{8}$ of an inch thick, being of the thickest sort of leather used for the upper leathers of shoes.

T V W X is a piece of hard wood, turned to the shape here represented, whereof the part T is of the same diameter as the cylindrical rod A B and V W, to the same diameter as the wood E F; then, having cut the piece of leather to about an inch more in diameter than V W, with a mallet striking upon the head of the piece of wood at X, the leather will be forced into the iron ring, and form the shape of a hat, and, with a knife cutting off the superfluities even with the outside of the wood V W, it will then be of a size proper for use; after staying some little time, release it, and, with a sharp narrow-bladed knife, cut out the crown even with the inside of the cylindrical part of the leather, and, by holding the blade of the knife parallel with the axis of the cylinder, it will give it the shape *a b c, a b c.*

The leather will be rendered more compliable, if need be, by being first wet, and will keep its shape better if suffered to dry in a thin hoop, whose inside is the same as the inside of the ring P Q; if it cannot be made without puckering, it is a sign, that the part T is too prominent, for even $\frac{1}{2}$ an inch of turn down will answer the purpose; dintle leather wetted is also more compliable than the common tanned.

It is to be observed, that the rods be drawfiled very smooth, and first of all worked with a mixture of soft grease and powder of black lead, and, afterwards, black lead simply.

It will, also, be of further advantage, in respect to the saving of water to lay the water about three buckets higher upon the wheel, according to the method first proposed for No. 1.

Austhorpe, February 11, 1769. J. SMEATON.

Answer to Queries by Messrs. Grieve and Benson.

Carron, July 10, 1769.

Mr. Gascoigne having shewn me Mr. Smeaton's letter to-day, in which there is the following query, viz.

"Mr. Grieve informed me, that at the rate I saw No. 4 a-going, viz., 18 cylinders per minute, that she did 30 baskets per day: query, what is her common rate of blowing, that is, how many cylinders in common with a full head, and how many baskets are then done?"

To which I answer, that 18 cylinders per minute is the usual rate of blowing at No. 4; that she blows down from 30 to 35 charges per day; she is not now allowed to go more than 18 cylinders a minute, which is performed at the lower gate at all times, and with the upper gate, when the pool is very full. Some time ago, both gates were used, even then she never went more than 21 or 22 cylinders per minute, nor more than between 30 and 35 charges per day, yet I have known her drive as many as 45 charges per day; such is the uncertainty of founding on the number of charges as the basis of a calculation.

He also informed me, that No. 3 made 15 cylinders per minute, with one gate, and 18 cylinders with both; query, how many baskets respectively?

To this I reply, that No. 3, with a full head, does make these cylinders; at this furnace we always blow with both gates, and, therefore, I cannot say how many charges she may run at 15 cylinders per minute; but at 18 she blows down from 25

to 29 charges per day, and if the water in the pool be 2 feet or 30 inches lower than full head, this No. 3 furnace will not drive above 15 or 16 charges per day.

Mr. SMEATON will please to advert, that a charge consists of several baskets of mine, coal, and lime-stone, which is put into the furnace when the materials are sunk in her to a certain depth; now, this charge consists sometimes of more or less baskets than at other times, just as the working of the furnace requires it; and it must, likewise, be observed, that the quality of the materials has great influence on the driving of the furnace.

JOHN GRIEVE.

When No. 1 blows 25 cylinders per minute, she will make 28 baskets per day.
When No. 2 blows 34 bellows per minute, she will make 20 baskets per day.

J. BENSON.

Mr. BENSON's Answers to Mr. SMEATON's Queries of the 11th, as far as they respect Nos. 1 and 2.

CARRON, July 12, 1769.

IN the first place Mr. SMEATON will please to observe, that the coals and lime-stones used in each furnace, are all of the same qualities, and nearly the same quantities; the difference is not worth notice.

Query 1st. Answer. The mines used in Nos. 1 and 4 are quite different qualities, so can only say what difference there is in the weights of the mine used to a charge; No. 1 charge of mine is about $\frac{1}{10}$ to $\frac{1}{12}$ heavier than No. 4; when No. 1 is running 28, and No. 4, 30 to 35 charges per day, supposing both furnaces of the same shape, but they are not, No. 1 blast is more repelled than No. 4.

Query 2d. Answer. The materials of Nos. 1 and 2 are much the same; the mine of No. 1 charge weighs about $\frac{1}{12}$ heavier than No. 2; this difference arises chiefly from the shapes of the furnaces, and not from the blast.

Query 3d. Answer. The quality of the iron in No. 1 may be as good when she runs 28 charges per day, as when she runs 18 and 23, provided she be working what we call clean natural mines, or mines not possessed of poisonous matters; but the quality of the iron depends upon that, and the quantity of mine used to a charge.

Query 4th. Answer. I never wrought No. 2 at 10 to 12 charges per day; but were that the case, she would take a double set of men to work her, and the iron would be so cold for want of its mother cinder, which cinder can only be produced in a blast furnace by a proper quantity of blast, it would be of no service but for pigs, and scarcely would run out of the hearth even into them.

JOHN BENSON.

Mr. GRIEVE's Answers to Mr. SMEATON's Six Queries, dated the 11th Instant, as far as they respect Nos. 3 and 4 B. Furnaces.

CARRON, July 12, 1769.

To Query 1st. The coal and limestone used to a charge is much the same in all the furnaces.

No. 1 carries commonly $\frac{1}{12}$ or $\frac{1}{13}$ part of more mine to a charge than No. 4, but it must be observed, that the quality of the mines used at No. 1 and No. 4 are always different, and to come at the ability of each, they should be loaded with equal materials.

To Query 2d. I reckon No. 3 carries $\frac{1}{12}$ or $\frac{1}{13}$ part more mine than No. 4; but this is as uncertain as the answer to query 1st, on account they are never loaded with the same sort of mine.

To Query 5th. With the same materials, I believe, No. 1 and No. 4 will make nearly the same quality of iron, yet there may be a difference in favour of No. 1, on account of her drier situation, and her better make.

To Query 6th. This depends entirely upon the nature of the materials; No. 3, when she drives 25 to 29 charges a-day, will make as good iron as when she drives only 15 or 16 charges a-day, provided, in both cases, she be working what we call wholesome mines; but if the materials are endued with any pernicious qualities, every furnace will make better iron by working than fast: The reason is obvious; by driving slow the materials remain longer in the body of the furnace, and so have more time to throw out their sulphurs, or the heterogeneous matter with which they abound, escapes by sublimation or attraction, which hard driving would carry down with and poison the iron.

JOHN GRIEVE.

Explanation for the Design of the Blast Machine for the Furnace No. 2, at Carron.

As in this machine I have the advantage of ordering the water-wheel, which I judge best to be over-shot, this circumstance reduces its height so much, that, by a small enlargement of the cylinders, it can be allowed to go at such a speed as to do without geer, which, however well they have answered in No. 1, where they were necessary, yet, where the same proportions in the movements can be accomplished without geer, are more properly avoided.

I have, also, chose, instead of making two regulator beams working a cylinder at each end, as in No. 1, to make four beams or great levers with cylinders at one end only; by this means, the strain of the crank always lying downwards, and bearing upon its brasses the same way as the water-wheel, will work more easy and pleasant, and be less liable to get a shake, and be out of order by continuance of wear. The whole, therefore, of the motions being performed with more ease and simplicity than No. 1, I expect it to be subject to less attention and repairs, and that it will not require above $\frac{4}{5}$ of the water to work it, taken by No. 1.

There will be more timber in the framing, but as it will be nothing but common fir timber, I apprehend this will be no object, and this will be more than saved in the water-wheel and axis, the spurn-wheel, and pinion.

No. 1 is a design for the upright of the water-wheel; it is here shewn to be of 20 feet diameter, but as, on my last view at Carron, I understand that the wheel No. 2 lies lower than the rest, and is sometimes affected by tail water, when Stenhouse mill-dam is full, a circumstance I was not before apprised of; in order to avoid that, it may, perhaps, be necessary to reduce the diameter of the new wheel from 20 feet to 19 feet 6 inches; but, yet, if Stenhouse mill-dam never throws above 3 inches dead water upon the bottom of the present wheel, then the new wheel may be laid as low as the present wheel, because that quantity of dead water, supposing the tail-watercourse from the wheel be open and free, will be of no prejudice to the going of the new wheel.

The reduction of the water-wheel to 19 feet 6 inches is, again, only upon a supposition, that the pond is subject to be reduced 1 foot 9 inches below head, as I saw it the 7th instant; but, if it is never suffered to go above 1 foot below head, as

advised in my report of this day, or, at most, 14 or 15 inches, then the water-wheel may be of its full size, though it should be obliged to be raised at the bottom from 3 to 6 inches, to sufficiently clear the tail-water.

The elevation here given is supposed to be of the outward front; but, as I find the tail-water goes off the contrary way to what is here shewn, and will require a different kind of penstock, for which I will send a particular design when I return to England, it will be proper to lay a sweep to the breast of this wheel, to fit it as close as possible; but it may either embrace the wheel a quarter round, or only $\frac{1}{8}$ of the circle, as is found most convenient in the execution: the two different ways are shewn according to the letters A B C and A D E.

The width of the wheel is supposed to be as great as the conduit will allow; as it will work steady like No. 1, no allowance need be made for shake.

No. 2 is a plan of the whole machine, and an elevation of one of the truss-frames and beams, with a section of one of the cylinders; upon which it is only necessary to observe, that as the method of framing the truss-frames is the same as No. 1, whatever difference there is in the disposition, will be sufficiently obvious from the draught.

It is, however, to be observed that, as, for the ease of casting, I have supposed the crank to be cast in two pieces, particular notice is taken that one of the heads be set a small matter atwist with the arms of the crank, that when the whole crank comes to a bearing in the box that couples them together, the arms of the first half of the crank may make a perfect right angle with the arms of the second; otherwise, if this circumstance is not attended to, the clearance necessary to get the box entered upon the two heads, will produce a shake, that when the whole comes to a bearing, the arms of the two halves of the crank will not stand square to each other, which will produce an inequality in the blast.

The crank end of the regulator beam or lever has a piece of cast iron A, which is to be made of such a weight as to overhaul the piston, which, for the sake of lightness in this machine, is to be made of wood, or as light of iron as it can be properly cast; the pistons, however, are to be leathered, as in No. 1; the proposed use of the weight at A overhauling the piston, is to prevent the crank-rod from changing its bearings upon the crank-neck, for, by always bearing downwards, it will be no matter whether the neck-collars be tight or not; so that the only collars that will be needed to be kept tight (which they very easily may, having but little motion), are the tops of the crank and piston rods, and the centre gudgeon of the levers.

B is a provisionary flanch, which is here shewn to be mute; the opening to be about 6 inches diameter in the clear, and the use is, that in case a perfect equality in the blast should be afterwards found to be preferable to all others, as I am at present much inclined to suppose, from hence there may be made a communication to an air receiver or vessel, which will fully effect that purpose.

Kerse House, July 31, 1769. J. SMEATON.

THE WATER AT CARRON.

The Report of JOHN SMEATON, *Engineer, concerning the Quantity and Disposition of the Water at Carron, from a View taken thereof the 7th of July,* 1769.

As the several blast furnaces at Carron are of different dimensions, work upon different kinds of ore, and take different quantities thereof at a charge, the wheels take

their water at different heights, and, at the time of this view, the pond from which they were supplied was so low, that the head of water upon each wheel was a good deal uncertain in the different penstocks; it is not to be expected that any very accurate conclusion can be drawn by way of comparison of the several machines, in regard to their powers of reducing the ores or mine into metal; yet, in attempting the comparison in the best way I am able, it appears to me, that several matters offer themselves which seem worthy of serious attention from the Company.

Amidst the uncertainties above mentioned, it seems impossible to fix upon any absolute criterion or common measure to which they can all be reduced. The quantity of metal produced from the furnace seems improper, because the poorest ore (I must presume) takes most labour of the furnace, and yields the least iron; the different quantity of air that each machine throws into its respective furnace appears also equally unfit, because if we are to judge by this alone, it will appear, that the machine No. 4 will, with an equal supply of water, throw out more air in a minute than No. 1; and this will also hold with No. 3; and, therefore, we must conclude, that the machine No. 1 is inferior to No. 4, and also to No. 3. A conclusion which I suppose must be rejected from all experience hitherto had, and, consequently, the premises from which it is drawn.

It remains, therefore, that the number of charges, as they do not much differ in weight, which each furnace can work off in a given time, relative to a given quantity of water, is the only handle we can at present lay hold of, and is, as I perceive, the same by which the managers and workmen reckon; and though, on the account before mentioned, it may not be very exact as common measure, yet I find the differences of the effects of the furnaces relative to a given quantity of water are so very remarkable, that though our conclusion formed from thence will be short of perfect accuracy, yet they may enable us to adopt a better distribution of the water than at present.

The distribution and effects of the water on the day of view was as follows:

Table 1

	Strokes per minute.	Charges per day.	Cube feet of water expended per minute.
No. 1	19	23	267
2	28	18	555
4	16½	30	780
Total charges per day		71 with	1602 cube feet of water per minute.

N.B. At this time No. 3 was standing still.

When all the furnaces have a full head and supply of water, the number of strokes of the cylinders and bellows per minute, relative to the number of charges per day, as per information of Messrs. Benson and Grieve, are in the following table; and, comparing the several heads of water and apertures that these must obtain with the present, the expense of water relative to those strokes and charges will also be as therein specified.

Table 2

	Strokes per minute.	Charges per day.	Cube feet of water.
No. 1	25	28	481
2	34	20	761
3	18	27	1362
4	18	32½	852
		107½	3456

Now, comparing the respective numbers in the second table with those of the first, it appears, that the quantity of water expended to drive an increased number of charges, greatly exceeds the proportion in which the number of charges increase;

for taking the totals, to advance the charges from 71 to 107½, that is, nearly as 2 to 3, the water must be increased from 1602 to 3456, that is, more than in the proportion of 2 to 4. Again, in the furnace No. 1, to advance the charges from 23 to 28, the water must be almost doubled, and the disproportion, greater or less, is observable in all the rest. Mr. GRIEVE reports, that respecting the furnace No. 3, with the upper gate drawn alone, with a full head of water, it will give 15 cylinders per minute, but with both gates drawn, in which case the expenditure of water will be doubled, the number of cylinders are no more than 18; and as it otherwise appears, that the quantity of charges relative to each furnace is almost, but not quite, proportionable to the number of cylinders, in the furnace, also, the disproportion between the water and the charges is as great as in any of the rest, and, indeed, the proportion, though in somewhat different degrees, appears from the united testimony of the machines of every construction.

Observing this disproportion, and my mind suggesting to me the use that might be made thereof, towards a better allotment of the water, I found it necessary to know whether the iron produced by the several furnaces at their low rates of working was as good as the iron produced at their higher rates of working; and from the answers I have received from Messrs. BENSON and GRIEVE, it appears, that the low rates of working produces quite as good iron as the higher, and in cases of impure mine, considerably better; however, it seems there are rates of working so slow, that the iron would not be put in a sufficient fusion, as would happen if No. 2 was reduced from 18 to 10 or 12 charges per day.

From a diligent comparison of the above particulars with each other, and also with the theory which they ought to conform to, if the experiments could have been made with accuracy, I have endeavoured to settle the proportions in which each furnace would work with an equal distribution of water, according to the quantity in which it was used during my observations on the day of trial, which, according to table 1, was at the rate of 1602 cube feet per minute, say 1600; by this means we shall be enabled, in some measure, to enter into the merits of each, as well as to elucidate some other points. Supposing, then, the 1600 feet equally divided amongst the whole four, each will work with 400 cube feet per minute, and their several performances may be expected as follows:

		Strokes.	Charges.	Cube feet of air per minute.
Table 3	No. 1	23¾	27	1194
	2	25	16	
	3	12	18	1459
	4	13	24	1811
	Total No. of charges		85	
	Ditto per table 1		71	
	Difference		14 in favour of disposition table 3.	

If we suppose 1600 feet of water divided equally amongst the three furnaces of table 1, they will each have 533 cube feet per minute; they may then be expected to move as follows:

Table 4	No. 1	26	29	533 cube feet per minute.
	2	27½	17½	
	4	14½	26½	
	Total number of charges	73		
	Ditto per table 1	71		
	Difference	2 in favour of disposition table 4.		

N.B. This last disposition, though it advances the number of charges by two, yet as it throws more work upon Nos. 1 and 2 collectively, and less upon No. 4, which works single, I suppose the convenience upon the whole may be less.

The following equal disposition of the water amongst three furnaces may, perhaps, answer better, as it not only makes a better produce, but divides the work of the two houses more equally.

		Strokes.	Charges.	
Table 5	No. 1	26	29	533 cube feet per minute.
	3	13¼	19¾	
	4	14½	26½	
	Total charges		75¼	
	Ditto per table 1.....		71	
	Difference		4¼ in favour of disposition table 5.	

From the above disposition I deduce the following probable inferences:

1st. That the number of charges does not depend wholly upon the quantity of air produced by the machines, but, in a great degree, upon the regularity of the blast.

2d. That the number of charges does not depend upon the velocity wherewith the air is thrown into the furnace, but rather upon the quantity of air that is made to pass regularly through the materials contained in the furnace in a given time.

3d. That this quantity so made to pass may have its limits, for too much may spoil the metal by over-heating it, and too little will not produce heat enough to give it, and keep it in, the necessary state of fusion, and which limits can only be ascertained by experience.

4th. That the worst machine is capable of working a given number of charges with less expense of water than will be required to be added to the best, to advance its produce by an equal number.

6th. That the most advantageous way, when water is short, is to keep down Nos. 2 and 3 to as few charges as can be admitted to do their business well, in point of quality, and to divide the water, after these are served, equally betwixt Nos. 1 and 4; but when No. 1, so served, runs above 28 charges, or No. 4 above 30, then such overplus to be equally drawn upon 2 and 3, and so on, upon the waters mending, till they are all advanced to their highest pitch, and the contrary method upon its decline.

We will now examine the real supplies at the times of shortest water, and endeavour to ascertain the best means of using it.

From the gauge of the river's water taken at the long arch, it appears, that at that time it amounted to 990 cube feet per minute; but as the water was said to come down more in the day than the night, on account of stoppage of mills above, and also that sometimes by continuance of drought runs still shorter than at present, it was thought it was in the greatest scarcity on an average not more than ⅔ of what we then measured.

The fire-engine at that time went from 6 to 8 strokes per minute, of 5½ feet each; but as she was frequently obliged to stop to gather steam, this with other stoppages in the 24 hours, together with the loss by shutting of valves, makes me reduce her average rate to five strokes per minute at 5 feet each.

	Feet.
The fire-engine will therefore raise per minute	440
And the river Carron at lowest	660
Total	1100

I understand from Mr. GRIEVE, that No. 3 makes good iron at 15 charges per day, and from Mr. BENSON, that No. 2 will not answer at 10 or 12; but I will suppose that No. 2 will work as well at 15 charges as No. 3 does, and as they are allowed to work well at that rate, they may be supposed to do so at a somewhat smaller rate; dividing, therefore, the 1100 feet equally amongst the four furnaces (which reduces Nos. 2 and 3 nearly to the rates above mentioned), we shall have as follows:

Table 6

	Strokes.	Charges.	
No. 1	21	23·8	275 cubic feet per minute.
2	22	14·1	
3	10¾	15·9	
4	11½	21·2	
Total charges		75	
Ditto per table 1		71	
Difference		4 in favour of disposition No. 6.	

Hence, it appears, that in the lowest state of the river Carron, by disposition table 6, there will be 4 charges per day worked by 1100 feet of water per minute more than is done by disposition table 1 by 1600.

To complete this view, I will suppose all the furnaces equally perfect as No. 1, and that they are confined to the supply of the river Carron alone in its lowest state, that is, 660 cube feet per minute; there will be, therefore, a supply of 165 feet for each machine. These 4 machines with that supply will go 17½ cylinders each, and work 19½ charges, in the whole 78 charges per day, that is, 7 charges more without the fire-engine than they do with it at the time that the river Carron supplies 990 feet of water per minute.

In these computations I reject the circumstance that Nos. 1 and 3 carry about $\frac{1}{12}$ more weight of ore to the furnaces at the charge than Nos. 2 and 4, which is much in favour of the two former; but, as there appears to be several other differences of circumstances as well as those, I rather choose to take the whole in the gross from the number of charges, without dwelling on minute circumstances.

CONCERNING THE NOSE-PIPES.

It is suggested in the second deduction, that the effect of the furnace does not depend upon the velocity wherewith the air is thrown in, but rather upon the quantity of air that is made to pass regularly through the materials contained in the furnace in a given time.

My reasons for this inference are the following: that in all cases the number of charges worked by each furnace are, when proper deductions are made for the friction of the machine, very nearly proportionable to the quantity of air thrown in by the same machine, and, though it will hold equally true, that when different quantities of air pass through the same nose-pipe, the velocity will be proportionable to the quantity, and, therefore, in like manner proportionable to the number of charges; yet, as a double quantity of air applied to a double or two furnaces with an equal velocity, produces a double effect, it is most probable, that a double quantity of air producing a double effect in the same furnace, is also owing simply to the double quantity of air thrown in, the double velocity being only a concomitant circumstance attending the throwing a double quantity through the same orifice; and this appears still the more probable, as within certain limits a less velocity of air as effectually converts a proportionable quantity of mine into metal as a greater. Now, suppose any furnace, for instance No. 1, will do her work well at 14 cylinders per minute, in which case

she is said to dispatch 18 charges with a nose-pipe of 3 inches, if the machine is made to go 28 cylinders, and drive her air through a nose-pipe of double area, viz., $4\frac{1}{4}$, she would then blow a double quantity of air, and would only require a double quantity of water; but, if she is made to blow 28 cylinders through the same nose-pipe of 3 inches, it will require *eight times* the quantity of water, and yet the number of charges *scarcely doubled*, and the metal itself, at the best, no better, and, in some cases, not so good. Hence, appears not only the great advantage in point of water, of working a greater number of furnaces at low charges, rather than a smaller number at higher, but also the advantage of applying as wide a nose-pipe as can be admitted, so that the air may really enter the furnace, and not be repelled back again; and in this respect an equal blast will have very greatly the advantage over an unequal one; but I apprehend, that it may be practicably known when any part of the air is repelled, because when there is no sensible reverberation on the hand or face, it is evident it must enter the furnace. If, therefore, it should be found, that when No. 1 goes 25 cylinders, all the air will enter the furnace from a nose-pipe of $4\frac{1}{2}$ inches, or, for the sake of an addition of velocity to make it enter, suppose of $3\frac{3}{4}$, it will then work with 247 cube feet of air per minute, instead of 481, which, per Table 2, is requisite for the same number of cylinders through a 3-inch nose-pipe; and, consequently, if all the furnaces were equally perfect with No. 1, they would be capable, in the very lowest state of the river Carron (with the present help of the fire-engine), of doing more work then they now do with a full supply of water, and without the fire-engine would do more work than they now do with it.

After all, I do not pretend to determine that things will succeed exactly in this manner. The physical nature of bodies is not to be circumscribed by geometrical reasonings, which have only quantity for their object; all I mean really to investigate is, that if the nature and conveniences will, *upon trial*, admit of their being worked in the manner suggested, then such advantages in point of power will follow; yet I do not mean to say, that the advantages will follow precisely in the quantities I have set down; this is not to be expected, unless the data on which I have been obliged to proceed could have been more accurately had: however, notwithstanding a degree of inaccuracy in the data, I presume it cannot be so great but that the reasonings thereon founded will, at least, shew which way the advantage lies, and thereby furnish matter for experiments, which as they could easily be tried, and if attended with success will be of great consequence in the application of the present powers to the best advantage, I cannot but earnestly recommend the trial thereof as speedily as convenience will admit, which is the whole aim of what I have delivered.

CONCERNING THE IMPROVEMENT OF BLAST MACHINES.

No. 1 is now supposed complete, and a standard for the rest.

No. 2 appears at present to be the most faulty, but when rebuilt according to the plan given in with this report, I suppose will perform, at least, equal with No. 1 in making iron, and go with $\frac{1}{4}$ or $\frac{1}{5}$ less water.

No. 3 appears to take considerably more water than any of the cylinder machines relative to the number of charges; what preference it has in reducing those charges into metal I can be no judge of. I apprehend, however, it would be considerably improved in its present form, if the two blow-pipes were connected by an air-chest furnished with valves, and from thence to blow from one nose-pipe. As this alteration may be easily made it seems worth the trial; but I apprehend it will never perform quite well till it is put into the form of either Nos. 1 or 2.

No. 4 will, I apprehend, perform nearly with No. 1, when furnished with a fourth cylinder. This I suppose, because when their effects are compared when working with the same quantity of water as per table 3, the difference is not much greater than what should arise from the wrong proportion of the parts of No. 4, which will be, in a great measure, corrected by the addition of a fourth cylinder.

It would be a saving of water in the whole, if the pond of Carron was never suffered to go lower than from 6 inches to a foot below a full head, and rather than suffer that, to draw the necessary water from the reservoir at Larbet, or to reduce a number of cylinders blown at each machine, according to the proportions suggested in tables 3d and 6th.

CONCERNING THE BORING MACHINES.

	Cube feet.
The over-shot wheel in boring a gun of 6½ inches, used per minute	341
The cutting-machine	168
Together	509
But as one cutting-mill supplies two boring, subtract half the cutting-mill's water	84
Neat quantity expended to keep a cutting and boring machine at work continually	425

In regard to the small boring and turning mill at the side above, I find it takes 495 cube feet per minute; but, as I understand it only goes when there is a full head and plenty of water, I lay it out of the consideration.

It appears, then, that to keep one boring machine, with the necessary cutting, going continually, they take near ⅔ of the whole produce of the river Carron in short water times,—that is, almost as much as the fire-engine draws; and though these machines be supposed to go only 12 hours in 24, yet they will still consume as much water as will work the furnace-machine No. 1 at 22 charges per day; a destruction of power which has been very properly seen by the Company, and, therefore, proposed it as very desirable, that those machines should be entirely silenced in short water times, and a new one erected in lieu thereof upon the tail-water proceeding from all the furnaces collectively.

Now, if these 2 machines require 569 cube feet per minute to work them when there is a fall of, at least, 20 feet, a fall of 6 feet (which is the utmost I think can be well had for the tail-water into the tide's way) will require 1697 feet; whereas the river Carron does not supply half of this water in very dry seasons, and the engine-water will not apply itself to this machine; notwithstanding, I can assure the Company, that I can undertake to furnish a design, wherein the water can be applied in so superior a manner, in point of power, to what it is to the present machines, that the river Carron, at 660 cube feet per minute, upon a fall of 6 feet only, shall drive those machines as effectually as they are now driven with 509 feet upon their present head.

Kerse-House, 31*st July*, 1769. J. SMEATON.

RESOLUTIONS OF THE CARRON COMPANY.

At a monthly Meeting of the partners of Carron Company, held at Carron, 10th August, and following Days, 1769.

Present, Mr. John Adams, Mr. Cha. Gascoyne, Mr. Thomas Roebuck, Mr. Wm. Cadell, Jun., and Mr. John Cadell.

Mr. SMEATON's report of the 7th of July last, made in consequence of our letter, dated July 1, having been read to the meeting,

Resolved, That the said report be approved of, and that the necessary steps be taken, as soon as convenient, to make such trials and experiments of the use and distribution of the water, according to the tables contained in the said report.

Resolved, That Mr. SMEATON be requested to give the company a scheme and plan of the boring-mill mentioned in his report, as soon as it suits his convenience.

Resolved, That the thanks of the meeting be transmitted to Mr. SMEATON, as a mark of the sense they entertain of the attention he is pleased to pay to their works.

CHA. GASCOYNE, P.

Some Remarks concerning the Design for a double Boring-mill for Cylinders and Guns to be erected upon the Tail-water of the Carron Works.

I propose the machine to be erected upon the opposite side of the tail-watercourse to that on which the blast-furnaces stand, and in any part of the yard that upon the whole shall be thought most convenient, which, depending upon a great number of circumstances that I cannot be acquainted with, must be judged of by the Company; nor is it at all material to the action of the machines, whether they stand as close to this watercourse as they can well be disposed of, or be carried further into the yard. According to the general design No. 1, it is proposed to turn the tail-watercourse of these mills a quarter round, so as to proceed nearly in a parallel direction to that of the present course to Stenhouse mills, and to fall into the tail-watercourse at Stenhouse mills, at such point as shall be thought most convenient on account of digging, separation of lands, &c.; but, in case the tail-watercourse is made to fall into that of Stenhouse, above the lowest point to which Mr. LAURIE levelled, it will be necessary to clear up so much of the old watercourse as shall prevent any material loss of fall between that lowest point and the falling in of the new watercourse.

Mr. LAURIE makes a fall of 8 feet 5 inches from the *bottom* of the furnace tail-lead, at the lower side of the bridge next below the boring-house, to the lowest point to which he levelled, but, as the furnace tail-lead will be charged with some depth of water *above its bottom*, before the tails of any of the furnace-wheels will be affected thereby, we may account the whole fall, from surface to surface, to be somewhat more than he has stated. In the present design, I have supposed a neat descent at the mill of 7 feet only, for this principal reason, that I observe the ordinary spring-tides flow within about 3 feet of the top of Stenhouse mill-dam, and, as the neap-tides flow within 4 feet at the height of the spring-tides, I have, therefore, laid the wheels so that they may not be interrupted daily by the tides. I propose, therefore, that an over-fall of 50 feet length in the crown be erected at or near the place where the present one now is, at Stenhouse mills, to be laid 3 inches lower than the height of the water in the tail-watercourse at the works, when the wheels there are just free of tail-water, by which means the whole water will be vented over the over-fall, without affecting the furnace-wheels, when the tail-mills are all shut; the height, therefore, of the water, marked in the design for the water-wheel to be of 1 foot 3 inches above the crown of the fall, will be 1 foot 3 inches below the top of the over-fall; and, allowing 2 inches for the run of the water from the works to the over-fall, this crown will be 1 foot 8 inches below the highest state of the water in the tail-watercourse, that will not affect the furnace-wheels; but, in case all the water from the furnace can be pent over Stenhouse dam without putting them in tail-water, then this over-fall will be unnecessary. The rest of the fall to Mr. LAURIE's lowest point

of level will be 1 foot, or something better, for declivity between the boring-mills and the said lowest point; but, if it shall appear, upon further examination, that the wheels can be laid lower than I have supposed, without being affected by the ordinary neap-tides, then I would add so much to the fall of the mills marked in the said water-wheel design 5 feet 9 inches, keeping the crown of the fall at the same height respecting the furnace-wheels, or not exceeding 1 inch or 2 lower, and for which, if necessary, I will send a new curve for the fall, every thing else remaining the same. It is, therefore, the height of the neap-tides at high water that determines me as to the fall to be taken at the boring-mills; and, as this height will not be diminished by any cut that may be made on the loops of the river below, that circumstance may fairly be laid out of the question, there being at present more descent to Reay's Ford than can be taken in, for the reasons above mentioned.

The power required for boring depends so much upon the circumstances of the thing to be bored, that it is a matter that cannot be reduced to any exact calculation; but this I am not in the least doubtful of, that, in the very lowest state of the Carron water, it will carry the gun-mill with two guns boring and one cutting off, which is, I apprehend, more than the three machines at present do, and that, in all ordinary times, the cylinder-mill, requiring less power, may be worked at the same time. It will, however, be necessary that the mill-gates, &c. at the Stenhouse mills be kept in good repair, otherwise a quantity of water will be expended there in leakage.

The rings of the two water-wheels I have designed to be of cast iron, in order that they may act as loaded flies, and thereby preserve the motion more steady.

I have supposed all the axes to be of cast iron, with fluted heads instead of squares, to keep them from wearing off the corners, and are what I would recommend: but forged iron spindles with square ends may be made use of instead thereof, if better approved of, for reasons I don't see. I have shewn the same fluted heads upon the two ends of the water-wheel axis that are next one another, by means whereof, if an extraordinary occasion should offer, the power of both wheels can be combined so as to act on either side.

I have been in some doubt whether so large a wheel as is represented for boring the large cylinders could be cast upon that plan; if not, the same sized wheel of 78, as is represented on the main axis for guns, being applied on each side, answers to the mean motion for cylinders; and I apprehend it may be worth while to have two motions, as the wheel will bore two cylinders at once, or a cylinder may be placing on one carriage and got ready while the other is boring; as the motions stand in the plan they answer nearly to 3, 2, and 1.

If it is found convenient to have the boring-mills so much further from the furnaces that the gangways may come towards the present tail-watercourse, then the quarter-round turn may be made in the new lead to be cut from the same to the new mills, so that the tail-water of the boring-mills will go away directly without any turn. I don't mention this as preferable to the situation in which they are shewn in the plan, but as a hint to shew the different situation in case it should happen to be more suitable to the general convenience.

N.B. A beam, being supported aloft across the three gangways for the guns, with a tackle hanging from a running roller upon the beam, will take up the gun from the gun-head carriage, and put it upon either of the boring carriages. The same may be done by a crane in the middle.

The width of the new tail-watercourse should be a 10-feet bottom with proper slopes, but, where walled, 9 feet will be sufficient.

Concerning the alteration of the present mill for cylinders and gun-heads, if the

same motions are adapted thereto as are designed for the new mills, they will equally answer. But it would go with still less water, if the wheels were made so much lower as to be overshot.

In its present state it would go with far less water, and do its business better, if the motion it now has for gun-heads was adapted for cylinders, and the cylinder motion (that is, of the great axis) was applied to the gun-heads; if made new, it would be right to use iron rings for the sake of the weight, whether of its present size or reduced to an overshot.

Austhorpe, October 15, 1770. JOHN SMEATON.

Explanation of the Design for building a Dam for the Carron Works at Duni Pace.

This design is made upon a supposition that the bed of the river where it is to be built lies about 7 feet below the level of the pen required. Mr. Gascoign's letter of January 16, acquaints that the bed of the river is 4 feet deeper than the top of the sill of the flood-gates; supposing, therefore, the water over that sill at dam's height to be 3 feet, the whole height of the dam's crown above the bed of the river will be 7 feet, as drawn in this design, of which the declivity of the slope surface of the dam is intended to be 5 feet; but, if the height of the dam's crown should require to be either higher or lower by 1 foot, it will make no material alteration in the design; for, if it is higher than 7 feet, as it is presumed that this is reckoned from the deepest part of the bed of the river, there is no need to increase the declivity of the slope surface of the dam between the crown and the skirt; but, if it is lower than 7 feet, the slope of the dam may be diminished so much as to leave the skirt about 2 feet above the bed of the river.

It is obvious from the design, that the body of the dam is intended to be of quarry rubble; and as the greatest part of what relates to it will be readily comprehended from the design, it will be sufficient to explain those things that are less obvious.

A B, Nos. 1 and 2, represent two courses of flags, or flat stones, from 2 feet to 3 feet square, or oblong, as they can be got, and of 4 or 5 inches thickness; those flags are proposed to form the grand stop or pen of the water: if the whole bed of the river at the place where these rows of flags are to be footed can be come at, so as to get them inserted about 1 foot below the bed of the river, it will be sufficient without any piles for footing the same upon; but, if this should prove otherwise, it will be proper to drive a row of grooved sheet-piling, as represented at C C, No. 1, supported by a string-piece D, and that supported and trenailed down upon the bearing-piles D E; this piling to be carried on at least across such deep part where a proper footing for the flags cannot be come at, and the terminations secured with the projecting part of the flags so as to make nearly a water-tight joint; but, were it not on account of expense, it would be still more eligible if this row of piling was carried quite across, and inserted into the dam's end walls.

At any rate, the first thing to be done is to lay in so much rubble as will support the sloping flags, and fill up the downstream side of the sheet-piling, so as to break the fall of the water over them, at the height of the ground-line D F; while this is doing, it will be proper to go on with the sheet of plank-piling at the tail of the dam G G, supported in like manner by the string-piece H, and that by the bearing-piles

H L, and the whole is covered by a 2-inch fir plank, to preserve the parts above-mentioned from the wear of the water, and which may be renewed, when worn out in a course of years, without disturbing any thing upon which the solidity of the structure depends. This sheet of plank-piling in all grounds that are not rocks, is indispensable; but, as the use of them is not to stop the water, but to keep in the sand and other matter, if the expense of grooving the plank-piles is thought material, and the ground is sufficiently uniform to admit their being drove close, edge to edge, without grooving, then this part of the business may be dispensed with: by the time the tail sheet-piling is completed, the whole area betwixt C and G should be got filled with rubble, and the row of stones marked I, which are supposed to stand edgeways to the rest, are to be got into their places: in this situation the dam will be entirely safe from derangements by floods, which will go over the work without hurting it. As the work advances, the flag-stones A B are to be got in gradually, the apron of earth upwards of the flags, and the rubble and upstream setting as shewn in the section.

It is to be noted, that the two rows of flags are intended to break one joint upon the other, and to be scappelled so as to lie or to pack together tolerably true; the joints all the way up are to be well stuffed with fog or live moss, and to be bedded with the same between the two rows of flags; this will prevent the earth from being forced through the joints by the pressure of the water, and will render the whole perfectly water-tight, if properly attended to; the earth itself being guarded by the rubble and setting above it.

While the dam is raising, there is no doubt but that the speats going over it will scoop out the ground below the tail-sheeting, so as to become 2 or 3 feet deeper than the natural bed of the river; when this happens, the whole must be filled up with whin-stones, or, what is best, large whin-stones split into three or four pieces by powder, which will enable the angular fragments to stick together better than the whole round stones; and, if any derangement happens here by speats, which is the likeliest place to happen, it must be attended to, and supplied till the water makes its exit from the tail-sheeting by a regular declining current.

I think it not only unnecessary, but impracticable, to give directions about the building of the dam's end walls, as I cannot determine the situation of the body of the dam respecting the land on each side from any thing that is before me, and the method of returning the ends of the walls into the land, shewn for the dam at Larbet, will be sufficient guidance here; I have only to remark, that it will be proper to make those walls, for some space on each side of the crown of the dam, higher than any flood is known to rise, and that the back of these walls, where the ground is disturbed or new made, must be well covered or even set with quarry rubble, in case the flood-water is liable to get behind them from the adjacent haughs; for want of this precaution, I have in more instances than one known the river to make itself a new course round the outward end of the dam.

It will, also, be proper to make the crown of the dam about 3 inches higher at the ends than the middle, and especially towards that end where the water is disposed to act the strongest, when the crown does not make a line right across the river, which is not always proper.

TABLE

Shewing the Expenditure of Water, &c. in the Furnaces at Carron, inclosed in Mr. SMEATON's Letter to Carron Company of the 23d July, 1776, in answer to theirs of the 14th ditto.

Number of the furnace.	Tons per Day expended by each furnace.	Cube feet of air protruded per minute.	Velocity of the protruded air in miles per minute.	Proportional effect produced.	Power required in proportion to the effect produced by N. 2	Excess of power used more than in proportion to No. 2.
					Tons per day.	Tons per day.
1	11774	1288·7	8·838	100·672	10964	810
2	15760	1673·7	9·298	144·711	15760	
3	17630	1344·2	8·117	88·575	9647	7983
4	24972	1301·5	8·926	89·585	9757	15215
	70136				46128	24008

DIRECTIONS

And Observations concerning the Clay-mill to be Built upon the Tail-water at Carron.

THE water-wheel, its conduits and gate, to be in all respects the same as those of the boring-mill, except that the rings need not be of iron, observing, that, in order to preserve the same head of water over the crown of the fall, that the whole be laid a few inches lower, in order to allow for the run of the water from the yard of the works to the place of the clay-mill.

I suppose the rollers themselves to be nearly the same as those now used, and to be cast upon wrought-iron spindles or gudgeons; the principal difference here proposed, besides that of a very different proportion between the turns of the water-wheel and the rolls, is the addition of a fly to each roll, a larger to the driving roll, and a less to the roll driven; those are intended to keep the motion more uniform and steady, and so as not to effect the geer that drives them by the little inequalities in the passage of the clay.

These rolls are intended to go about 50 turns per minute, which, as it is considerably quicker than the present, it would greatly tend to make the work go perfectly smooth and pleasant, if they were but 18 inches instead of 2 feet length, and yet they by their greater velocity will dispatch more work.

The work is so placed that if stampers are desired, they may be applied for beating the clay, so as to prepare it for the rolls; but, if the grinding it to a fine tough paste would be of use, for this purpose nothing would equal the runners on the edge, such as are used for oil and gunpowder mills: this would perform the whole operation from first to last, but would not reduce the clay to the consistence that the rolls do, so speedily as the rolls. A work of this kind might afterwards, if found occasion, be added to the other end of the axis, or, in its present form, it is capable of having a boring apparatus, or even a forge hammer applied to it, if thought proper; for this reason, I would advise to make the building roomy (of which I suppose the water-wheel to stand crossways in the centre), or to leave room on each side for building. I apprehend the wheel will stand best crossways upon the present lead or leet, so that the building will range alongside thereof. In this case, the tail-water must be

turned with a quarter round, the more gentle the better, but, if need be, may be turned almost in its own breadth.

This water-wheel will drive two sets of rollers at once, at each end, or other equivalent works, and for one pair of rolls will go with so little water, that I believe you will scarcely find the corn-mill the worse.

Austhorpe, Feb. 21, 1767. J. SMEATON.

THE REPORT

Of John Smeaton, *Engineer, concerning the Quantity, Regulation, and Distribution of the Water for Working the Blast Machine for the Four Furnaces at Carron in Dry Seasons, together with the Improvements that may be made therein, so far as regards the Power of Water to be employed.*

In order to answer the above purposes, I shall not only found myself upon the observations I made myself upon my view thereof in October 1776, but, also, upon such deductions as may be made from a thorough revisal of all the observations I have formerly made, or that have been communicated to me, of the state of these machines, by the Company at different periods; and, the several computations thereon having in general been performed when I was from home, and thereby not having the opportunity of recourse to my former papers, they have been drawn up in different terms, and with different views of the subject; and, also, observing, in the course of my last view, some particularities which could not be so noticed when the measures were sent me, which would materially affect the calculation of the quantity of water expended, I have in the following table corrected the same, and reduced the whole to the same standard.

TABLE

Shewing a comparative View of the several Blast Machines as used at Carron, at different periods, from the Year 1769 *to the Year* 1776 *inclusive.*

	No.	Diameter of nose-pipe.	Number of cylinders.	Cube feet of air per minute.	Velocity of air per second.	Tons of water expended per 24 hours.
1769, working with short water,	1	3	19	1066	361½	10680
.. ..	4	2⅝	15·3	1820	803	31200
			Sum	2886	1164½	41880
			Mean	1443	582	
Ditto, with full blast	1	3	25	1403	475½	19240
.. ..	4	2⅝	18	2258	945	34080
			Sum	3661	1420½	53320
			Mean	1830	710	
1773, February, with full blast	1	2½	20	1122	547	
.. ..	2	2⅝	18	1255	557	
.. ..	3	2¼	17½	1237	747	
.. ..	4	2⅛	10	1183	577	
			Sum	4797	2428	
			Mean	1199	607	
1776, July, with full blast.. ..	1	2¼	23	1289	778	15245
.. ..	2	2¼	24	1674	818	15506
.. ..	3	2 7/16	19	1343	691	18210
.. ..	4	2¼	11	1302	785	25669
			Sum	5608	3072	74630
			Mean	1402	768	
Do. on view in Oct. with full blast	1	2¼	28	1571	947	16502
.. ..	2	2½	24½	1708	835	16047
.. ..	3	2 7/16	19	1343	691	15732
.. ..	4	2¼	12⅓	1459	881	17769
			Sum	6081	3354	66050
			Mean	1520	838	

From the above table it will evidently appear, that the machines, when worked with a full blast, have taken less and less water, ever since the first view in 1769. It also appears, that the quantity and velocity of the air does not observe any regular proportion to the quantity of water expended: but it appears, in general, that the less quantity of air is discharged from any given machine, and the less its velocity, the less water it will take to work it; this also is obvious from what occurs every day, that more water produces more blast in the same machine, and the contrary.

A state of the works in February 1773, I received from the Company, with this observation: " From our present experience of the matter, the number of strokes per minute, quoted in the annexed table, throws the air into each furnace with a degree of velocity sufficient to keep the hearths open, and to work each machine with due steadiness and regularity." Now, from hence it appears, in particular, (see

the preceding table, 1773), that the quantity of air discharged, as well as the velocity wherewith it was projected, was remarkably near the same in all the four machines, the mean quantity being 1199 cube feet per minute, and the mean velocity 607 feet per second, on supposition (as in all the rest) of its being discharged with an equal velocity; and as, at this season of the year, I can apprehend no scarcity of water, I must suppose the furnace then working with full blast and effect: and, as I am furthermore told, in the Company's letter of the 2d of March, that "for some years past we have fallen into the method of making the iron at the blast furnaces into pigs proper for remelting in the reverberatory furnace, for the purpose of working up our gun-heads and runners, which practice requires less velocity of blast than when we cast the guns immediately from the blast furnaces, and also admits of more regularity in the whole process; so that, perhaps, we can now manage with less water than it was thought we could have done in 1769 or 1773:" I say, these things considered, we may ground ourselves here, that if 1200 cube feet of air is thrown into each furnace per minute, and with a velocity of from 5 to 600 feet per second, we shall certainly have sufficient blast to keep all regularly going in times of scarcity of water. I am therein also informed, that many experiments having been made in consequence of my report of 1769, "from all which we can clearly collect, that a nose-pipe for our purpose should not be less than $2\frac{1}{2}$ inches, nor more than $2\frac{3}{4}$ inches." Suppose, then, that the nose-pipe to be settled at a mean between them, viz. $2\frac{5}{8}$, it is not to be doubted but a little less water upon the wheel when the furnace is new, and a little more when it is worn wider, will equally answer the end as a variation of the nose-pipe, as has been remarked by the workmen as necessary: 1200 cube feet of air per minute driven through this nose-pipe will produce a velocity of 532 feet per second; and that this will be fully sufficient to keep all regularly going, though, perhaps, not producing the greatest quantity of metal, is evident from the state of the furnace No. 1 in 1769 and 1773. The nose-pipe being now proposed the same in all, viz. $2\frac{5}{8}$, 1200 cube feet of air will be discharged per minute when the different machines go respectively as follow:

No. 1, $21\frac{39}{100}$ cylinders.
No. 2, $17\frac{88}{100}$
No. 3, $16\frac{97}{100}$ cylinders.
No. 4, $10\frac{14}{100}$

But as fractions may be inconvenient to the workmen, I will suppose that in short water times the several machines are regulated to the number of cylinders, as in the following table; and then the quantity of water that may be expected to be expended, proportionable to what I found in October 1776, is contained in the four last columns of the following table:

A TABLE

Shewing the Expense of Water according to the Regulation proposed for short Water Seasons, and according to different States of Improvement of the Machines.

No.	Cylinders per minute.	Cube feet of air per minute.	Velocity of air per second.	Tons of water expended per day, as per Oct. 1776.	Expense of water Nos. 3 and 4 improved.	Expense of water of all improved to a 23-feet fall.	Expense of water of all improved to a 24-feet fall.
1	22	1234	547	12966	12966	12312	11800
2	18	1255	556	11789	11789	10251	9824
3	17	1202	533	14076	12240	12240	11730
4	11	1301	577	15852	12312	12312	11800
				54683	49307	47115	45154
1	2	3	4	5	6	7	8

By the first table it appears, that the blast machines, as they were working in October 1776, were consuming at the rate of 66,000 tons per 24 hours; but by the disposition and distribution according to this last table, without any correction or alteration of the machines themselves, that quantity would be reduced to about 54,700 tons; and, as it appears that the principal defects of Nos. 3 and 4 arise from their not taking their water so high upon their respective wheels as No. 1 does, in case these two were altered so as that the top of their upper gates should be 23 feet above the bottom of their respective wheels, then the four furnaces may be expected to work with the quantity exhibited in the 6th column, viz. about 49,300 tons per day.

If all the four furnaces were furnished with upper gates, and No. 2 wheel made larger, so as all to take the water at the same height, viz. 23 feet above their bottoms, then they may be expected to work according to column 7, that is, 47,100 tons per day: and if they were all made to take the water 24 feet above their bottoms, then they would work as per column 8, that is, with 45,200 tons per day.

As No. 3 is proposed to have a high gate, and the wheel of No. 4 to be rebuilt, and as I suppose both will be done this summer during the season of scarcity, it appears that no other provision will be wanted for the approaching season than per column 6, that is, 49,300 tons per day, because, if one of the furnaces is laid off in order to be reformed, there will be a full sufficiency of water for the other three; for it is ascertained that the river Carron in its lowest state affords 660 cube feet per minute, amounting to 26,400 tons per day, so that a supply of 22,900 tons per day is the utmost that can be wanted to keep all going; and this quantity can be raised by the fire-engine in its present state at the average rate of $6\frac{1}{2}$ strokes per minute, which as she may very well perform, it seems advisable not to embarrass the progress of the other business by rebuilding of the engine this season, but to give her a good overhaul to render her performance secure.*

It will now be proper to inquire what is to be expected from the home reservoirs made and making, towards supplying the 22,900 tons per day, above stated as the deficiency of Carron in dry seasons; and I suppose the dam-head of Larbet is to be advanced one foot higher, and all the banks raised in proportion, so as to pen the water in the furnace-pool and bog-reservoir to 27 feet above the bottom of the furnace-wheels; these reservoirs are stated altogether at 36 Scots acres; and as each Scots acre upon 1 foot in depth contains 1521 tons, the 36 acres will contain 54,756 tons, and upon 3 feet depth (supposing the same surface at a medium) will be contained 164,268 tons, which, divided by 22,900, gives $7\frac{1}{10}\frac{7}{0}$ days.

Now, when 3 feet is drawn off from 27 feet, there will remain 24 feet, which will reduce the head upon the gates at 23 feet to 1 foot, and as this is as low a head as the water can properly act upon the wheels, it will then be time to open the lower gates to draw off the remainder. As the water will there act to a considerable disadvantage, it will be ineligible to use the engine, but when the furnace-wheels take their water from their upper gates; whatever, therefore, is drawn out of the furnace-pool below the 24 feet, must be replaced again before the engine-water can produce the proper effect upon the wheel; and, as this will create a pause or stop of the whole, it will therefore be proper that it be as short as possible; for this reason it would be proper to have a stop-sluice upon the lead in the narrow part east of Mr.

* By the way, the greatest defect of the present engine is the not having a sufficiency of steam; and for this reason, the speediest remedy would be to cast and set up a new 10-feet boiler in the manner of those at Cronstadt, which may be placed so as to serve the new engine when erected without a removal.

LOWE's house, to shut down when the surface is reduced to 24 feet, so that the Carron may constantly pay its tribute by cascading over the said stop, and then the furnace-pool only, properly speaking, with the bog-reservoir, will be emptied together below the 24 feet. Now, suppose that from hence 2 feet more is drawn, which will nearly empty the bog-reservoir, if the wheels take this water at 21 feet above the bottom, then they will expend by these lower gates, to produce the same effect as before, at the rate of 55,200 tons per day, from which deducting 26,400, the supply of Carron, there will want 28,800 from the reservoirs. I must here observe, that the quantity that we can in reality draw off, will be only from the bog reservoir, for what is drawn from the furnace-pool, will be again supplied from some resource above the 24 feet, in order to fill it to the level of 24 feet in common with the lead and Larbet dam, because what is reserved in the dam of Duni Pace, or elsewhere, in order to fill it, might, if not so wanted, have been discharged at the upper gates.* Two feet then upon 24 acres is 73,000 tons, which divided by 28,800 gives $2\frac{53}{100}$ days, and this, with $7\frac{17}{100}$ from the first 3 feet over all, makes in the whole $9\frac{7}{10}$ days water, a treasury very essential to prevent frequent stoppages, and those of short duration, but no ways adequate to the purpose of going through a long drought, which generally happens once in a summer.

We will now see how the account will stand, on supposition that the high gates are all fixed at 24 feet above the bottom of the furnace-wheels, instead of 23 feet before supposed, all the rest remaining as before stated. Now, as only 2 feet can be drawn off from the whole 36 acres, they will contain 109,512 tons; and on supposition that the effect is greater from a fall of 24 feet than upon a fall of 23 feet, in the proportion of 24 to 23, then the quantity of water before specified to be wanted at the high gates, viz., 49,300, will be less by $\frac{1}{24}$ part, viz., 47,200; from which, taking 26,400, the supply of Carron, there will remain 20,800 to be supplied from the reservoirs; and then 109,512 tons, the content of the uppermost 2 feet, divided by 20,800, gives $5\frac{26}{100}$ days. Again, we shall now have 24 acres upon 3 feet deep, that is, 109,512 tons in the content, and the lower gates being supposed fixed at 21 feet as before, we shall have the same divisor, viz., 28,800, which gives us $3\frac{80}{100}$ days, and which added to the former make $9\frac{6}{100}$ days; hence, it appears, that this latter proportion of 24 feet height of top-gates does not make so much of the reservoirs as of the former 23 feet height; but this regards only the *home* reservoirs, whereas all water treasured up above the level of these reservoirs will, doubtless, have an effect in proportion to the fall from the gate.

This inquiry, however, leads us once more to see how very inefficacious reservoirs are likely to be when applied to a long-continued drought; and there is nothing so likely to prove a sheet-anchor as a plain, simple, well-constructed, powerful fire-engine, which, when it does nothing, will consume nothing; and being plain and strong, will be always in condition to work when needed, and the several parts to be easily inspected, so as to see whether they are or are not in working order.

From the above comparison of fixing the height of the highest gates at 23 or 24 feet, they are so nearly alike that the difference may well give way to convenience; and, in this respect, unless that steps have already been taken in the works of Carron to the contrary, it would seem to me that the convenience would be in favour of the 23 feet; for, in the first place, it is indifferent to the engine, because she will draw at 23 feet so much water more than at 24 as the wheels will want to use. 2dly, Having been informed that the working of the forges is become so material an object,

* The communication-stop between the bog-reservoir and furnace-pool before such filling must shut in, so that when the furnace-pool is filled, the bog-reservoir may remain empty.

that it will be even worth while to assist them with engine-water, it will follow, that it will be worth while to assist them with what will be equivalent to it.

Now, on a former occasion I have laid it down, that a properly constructed engine of a 72-inch cylinder will, at 26 feet high, raise 56,000 tons per day; and supposing all the four furnaces reformed and regulated, so as to use, according to column 7 of the last table, viz., 47,100 tons per day, Carron furnishing 26,400, there will be only wanted 20,700 tons of engine-water to them, the remainder 35,300 tons to be thrown into the forge-pool: now if the upper gates are fixed at 23 feet, they at once take off as much water from the reservoirs as will keep the furnaces going above seven days, whereas the whole of the remainder will only keep them going about $2\frac{1}{2}$ days more; and if engine-water is to be raised for the forges, why not let off the 2 feet remaining in the bog-reservoir into the furnace-pools, and begin to work the engine $2\frac{1}{2}$ days sooner; for this will serve instead of so much engine-water to the forges, and then all perplexities will be avoided with respect to the use of different gates, as well as all attentions necessary to keep a quantity of water to refill the furnace-pool up to a level to work the upper gates, and also the necessity of a stop upon the lead avoided, as well as every attention to the use of it, so that the whole will be reduced to this simple point, that whenever the upper reservoirs are exhausted, and the lower ones reduced to 24 feet above the bottom of the wheels, then the engine begins to work, and continues till the water mends.

One thing, however, must be very carefully attended to during the working of the engine, and that is, as it only circulates the water without increasing its real quantity, that care must be taken when the engine is working not to allow the boring-mills more water than is coming down into the furnace-pool from Carron; and at the same time, during the working of the engine, that all the water drawn by the engine, and delivered into the pools, be regularly discharged by the furnace and forge-wheels, *together with the supply of Carron;* for, if less is let down than the engine draws, it will not only deprive the boring-mills of Carron's supply (which in those cases is *the whole they can be allowed*), but Stenhouse dam being reduced, the engine will want water to draw; again, if more water is let down than is drawn by the engine and Carron's supply together, then the surplus quantity, after Stenhouse dam is full, will either run over the dam, or be spent at the boring-mills; but either way the water will be lost to the furnace-pools, which will thereby be reduced without a possibility of raising them, otherwise then by stopping the boring-mills, and letting down no more water than what the engine will draw, and then the pools will rise by the continual influx of Carron. These matters, so very necessary to be regulated, will, I apprehend, be done by strictly observing the following rules, a proper person being appointed to see to the observance of them.

When the furnace-pools are reduced to 24 feet, let the boring-mills be stopped, either altogether, or at nights, but so long, and at such intervals, as to suffer no water to go over Stenhouse dam, drawing at the same time as much water at the furnaces and forges as will supply the engine; by this treatment, the furnace-pools will gradually rise to 25 feet by the continual influx of Carron, which in this case they should not exceed.

When you find it exceeding that height, allow a little more water to the forges, and before it begins to run over Stenhouse dam, let the boring-mills draw so much as to keep it under, but not materially reduce it; by this means the boring-mills can never have more than Carron affords, nor the engine less than its proper quantity, nor yet the forges more than the surplusage.*

* Perhaps the best husbandry of all, of the reservoir water, instead of throwing the lowest 2 feet of the

The only present difficulty is Stenhouse dam being leaky, and thereby letting a considerable part of Carron's supply escape, that should work the boring-mills; but having a lighter or punt upon the dam, if fine earth is scattercd over the whole surface of the slope, for 30 or 40 yards above the dam, or so far up till you come at the natural bottom, and this being stirred and puddled with cow-rakes by some pains of this kind of three or four men for a couple of days, I doubt not but that it may be rendered sufficiently tight for the exigences of the present year; but if you think not, if you will be preparing a quantity of stone and piling, such as was directed to be used at Duni Pace, I will settle the particular plan for it immediately at my return from the Derwentwater spring receipt, which, I apprehend, will be about the middle of May.

The most pressing thing for this year's service is to make the alterations at No. 3, and new wheel conformable to the above, 23 feet high, for No. 4; but if made 24 feet, as formerly proposed, then all the upper gates must be made conformable, and it will be advisable to have low gates about 3 feet below the other.

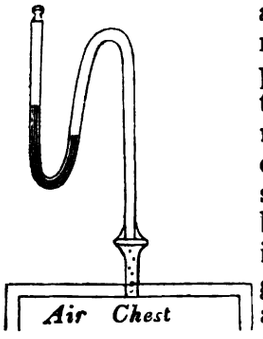
When No. 3 stands still, it will be worth while to get out and rebore the cylinder that is taper, as a considerable loss of power appears to be there; and when No. 2 is stopped, it will be proper to restore the original conveyance-pipes, as not only the straightness of the pipes of 7 inches, since supplied, but the driving the air through a box, when it is unconfined, to a particular direction, is, as I have experienced, a considerable loss of power. The best thing that can be done with No. 2 wheel, will be to clear it of the present buckets and shrouds, to mortice the rings for 16 studs in each, and upon those apply new rings, which, on account of being supported in 16 points instead of 8, need not be above half the scantling of the others; then clothing these new rings with new shrouds and buckets, it may be made the same size as No. 4, the axis and crank being raised on chocks, and the crank-rods shortened, leaving all the rest, inside the house, standing as at present. The water penstock must also be raised, but if made 24 feet high, should have a lower gate like the rest, and then it must be bucketed the contrary way, and have a penstock of a different kind to throw the water back, in which, however, near 6 inches of perpendicular will be lost; so that to draw down the pool to 24 feet, leaving 1 foot head upon the penstock (the over-shot wheels to go the reverse way), cannot be more than 23½ feet high.

In regulating the nose-pipes, I would advise their being brought to a clear regular surface inside, to some distance back from their very nose; and if those that are too small are bored to the gage of 2⅝ inches, so as to leave the nose part a cylinder, I have experienced it in water to throw out a more clean and less scattered column. An attention to this and also to keep the tuires as narrow as possible, so as just to receive the column and no more, I am convinced of it, will be found very beneficial in regard to the saving of power, or rather to make the very most of the power stipulated.

The best practical way of keeping the machines to the number of cylinders specified in the latter table, will be to furnish each furnace-keeper with a minute-glass, such as are used by the shipping for the log; they must, however, be ordered on purpose to be an *exact minute,* because those made for sea are generally some seconds short, for reasons given by mariners. I have now a couple by me, which I got made in Wapping, for experiments, in a better manner than common, instead of sand being

bog-water immediately into the furnace-pools, will be to let it out gradually thereinto in such quantity, as being expended at the forges, it will, together with Carron's supply, fully work the boring-mills.

furnished with granulated lead, and are very exact; but after all, unless the leathering of the pistons could always be keep equally tight, an equal number of cylinders will not always give an equal quantity of blast; but if, when the leathers are in their best state, the furnaces were furnished with a gage, consisting of a glass tube, fixed with cement to a bored brass stopple, as per margin, with a little quicksilver, this applied to a hole in any part of the air-chest, or general conveyance-pipe, by observing the height that the quicksilver rises in one leg above the other, as much water applied to the wheel as will raise the gage to the difference experienced, when all was tight, will not only in all states of the leathers reduce the machine to the same degree of blast, but discover when the leathers are defective, because then it will require more cylinders to keep the same difference of gage. These gages need only to be applied occasionally, when any deficiency is apprehended, and 1 or 2 may serve the 4 furnaces. If the top of the tube, which is properly to be open, has a bit of porous cane by way of peg, it will not only prevent the quicksilver scattering out, but prevent its vibrating so much by the inequality of the blast.



Austhorpe, April 6, 1777. J. SMEATON.

P.S. I do not find I have given an answer to that letter which transmitted to me a sketch for the new furnace No. 5, for my approbation, being upon the construction of No 2, only the water-wheel placed between the four cylinders, that is, a pair on each side, to which, if you find it more convenient in point of situation, I see no objection, or, if otherwise, no preference. It would be better with respect to the necessary speed of the water-wheel, if the cylinders were not quite so large as No. 2, viz. about 4 feet 3 inches; but as I apprehend you have already a set of models for the bottoms and air-chests ready made, by which No. 2 were cast, it will answer nearly the same end if you somewhat shorten the stroke, that is, not to exceed 4 feet. The wheel should be overshot, and the same height as No. 4 is to be made, and No 2 to be raised; but by all means let the air-chest be continued to join cross the separation of the two sets of machinery, and the blast-pipe go out from the middle in the most direct manner to the tuire, and to taper, from the size originally proposed for No. 2, from the air-chest to the nose-pipe.

In considering further upon the proposition contained in the note annexed to page 8, it appears still more advantageous, if you were to keep part of the water in Duni Pace reservoir to apply in the same manner; for, by this means, the boring-mills need never be short of water, nor yet any reservoir water misapplied on supposition of the forges being supplied with engine-water, or what is equivalent, and by reserving thus a sufficient part of the reservoir water, it will even answer to the leakage of Stenhouse dam, suppose you cannot get it tight in the way I have mentioned.

Keswick, April 10, 1777. J. SMEATON.

DESCRIPTION

Of the Apparatus for putting in Motion, and Discharging any of the Particular Motions for Boring the Gasconades at Carron.

Fig. 1. The dotted square *a b c d* represents the square end of the axis of the water-wheel, or any of the side motions driven by toothed wheels therefrom as usual, and whether this is a plain square or citadel head, is here immaterial. To this square end is firmly attached an arm, A B, which spreading both ways, C D, and applying itself to the angle of the square, this, by means of a similar piece, E F G, and a couple of bolts, the arm is brought on perfectly firm and solid, and will, therefore, continually revolve with the axis. At A is a mortoise, through the arm, 3 inches broad, and about $1\frac{1}{4}$ wide, capable of admitting a piece of iron faced with steel, and hardened, shaped somewhat like a blunt plane-iron, but $\frac{5}{8}$-inch thickness, so as to fill up exactly half the mortoise, and, consequently, its working or steel face will be in the direction of the radius; the other half of the mortoise is occupied by iron wedges for fixing it: upon this arm may be supposed to be imbossed, but in reality cast along with it, in the same piece a projecting part, B *e f g h*, before the plane C D, and also before E F G, being attached to the former, but detached from the latter, which projecting piece terminates forward in the ring *i k l m*, which forms a socket H, also cocentrical with the axis, and firmly connected therewith, which being fully understood the rest will be easily comprehended.

Fig. 2. The square *a b c d* represents the square of a detached axis; the dotted circle, *e f*, represents the size of a gudgeon, which is adapted to the socket H in the former figure: C D are two projecting arms, that, with the axis and gudgeon, form a +, as will be readily understood from fig. 3, which represents a part of the plan of the detached axis, and wherein the same letters refer to the same parts as fig. 2. The centre of the cross C D is pierced lengthways, with a smooth hole capable of receiving an inch-and-a-half, bolt, upon which, as a centre is hung in fig. 2, the arm E F G H I K L, which, in like manner, contains a mortoise at F, of equal size and distance from the centre, as the former one at A, proposed to hold, in like manner, a steeled iron tooth or kamm, like the former, each made to project about an inch from their respective arms, and the steeled faces being contrary ways, they will meet one another with their flat faces; and it being supposed that the gudgeon *e f* being introduced into the socket H, fig. 1, that when the two kamms are engaged, the detached axis will be made to turn along with the original one, whose square is *a b c d*, but not otherwise; this will now be made more plain by

Fig. 4, wherein M is a part of the square of the original axis, N the road, O the square head seen upon the angle, as at *a b c d*, fig. 1, H the gudgeon of the detached axis, P the bolt-hole through the arm fig. 2 and +, Q the main body of the detached axis, R the road (not to confine it while turning the gun, but to support it when the gun is taken away), and S the square socket, that receives the square at the breach of the gun, by which it is turned round; the two arms in this figure being marked with the respective letters, as the correspondent ones, figs. 1 and 2, will receive a sufficient explanation, especially when it is observed further that T is a stud cast upon that arm, which is acted upon by V, a strong spring sufficient to give the arm E F G a constant tendency to go towards the arm A B, and *n o*, in dotted lines, is a staple to stop the stud and spring from rising too far, and from carrying the arm beyond its due position.

Now, *p q* represents the kamm of the arm F G, and *r s* representing the kamm

of the arm A B, which overlaying one another, the arm F G will necessarily be compelled to go round with the arm A B so long as they remain in this position; but to disengage it, the outlaying part of the arm E F meeting in a certain part of its revolution with an inclined plane (of wood faced with a plate of iron), that can at pleasure be interposed, this plane or wedge by acting upon the outlayer so as to separate the two arms, the kamms will be released from each other, and the outlayer, resting upon a projecting part of the wedge, will remain at rest, the other arm continuing its revolutions. The gun is then to be removed as at present, and when another is adapted to the square at S, there is nothing to do but to draw away the inclined plane or wedge; the spring throws out the arm F G so as to form a right angle with the axis, and the next time the kamm *r s* meets the kamm *p q* it will quietly lay hold of it, and take it along with it, and so continue till discharged as before.

N.B. It is necessary that the edges of the kamms at the leaving each other should be parallel; for this reason they must not be square, but inclined according to the line *r t*; nor must the edges be quite sharp, but a little rounded; and as the continual chafing of the guns may wear the socket S faster than might be convenient, this socket may be cast with a citadel head large enough to inclose a piece with a common square within it. If the strength of the spring is not found sufficient to keep the arms together when in full strain, it is only making the kamms a little proud at the leaving edges, so that being a little matter out of parallel with the axis, they may be made so as to draw themselves together.

EXPLANATION

Of the Apparatus for Holding and Pushing forward the Boring Bars for the Carronades without a Carriage.

A B C D is the section of a square socket of cast iron, 5 inches square and 2 feet long, which is to be firmly bolted down upon a proper blocking of wood.

E F is a square of iron of the same size, and 2 feet 2 inches long, which must be fitted to the former with some degree of curiosity, so as to slide easily, and with as little shake as may be; this solid piece is to have a tapering square hole at each end, proper to receive, as a socket, the square of the boring-bar. This would in reality only be needed at one end for fixing the bar G G; but, as it may be subject to wear, the lasting will be doubled by having a similar socket at each end.

At the opposite end of the solid piece, the piece H is inlaid for receiving the point of the screw I K, by which the solid piece and bar are to be forced forwards. L M N is a lever of wood, footed at bottom in two strong staples O P, one on each side; the lever L firmly bolted and supported by the solid blocking.

Q is a brass or a wrought-iron box for the screw, hung upon trunnions as *q*, so as to give liberty to the threads of the box closely to fit and embrace the screw, notwithstanding the different position of the lever L M N.

N R is a bar of iron, by which the top of the main lever is connected with a secondary one, whose centre of motion is supposed to be at S, and which, going upwards beyond the limits of the paper, is represented to a smaller scale *s r t*, where there is attached a single block with an 8 or 9 inch light sheave, and a rope of about 2 inches circumference being reeved, as shewn and passing over the fixed pulley *v*,

the weight W will force the point of the screw against the piece H with any degree of force required; and as I do not expect the great lever to work kindly, when more than 1 inch out of perpendicular at the height of the screw, this will give it leave to act by the weight through a space of about 2 inches, when the person attending, setting forwards the screw by means of the fixed bar T X, brings up the lever and weight into its original position, and so on, till the bore is carried on to its proper length. The apparatus, in the proportion here designed, will admit of a chase of near 30 inches length, which, I apprehend, will be fully sufficient for your 24 pounders.

N. B. I am told, that a bit, whose cutting edges are brought to a proud edge by being filed to a hollow, as is shewn at *x y*, is marvellously good for boring holes in cast iron; but in this case the two edges cannot be brought into one, but the obtuse angled edge, formed by the thickness of the metal of the bit, joins the two cutting edges crossways, and forces itself forwards by being near the centre, but requires a considerable pressure. I am told that 800 lbs. weight will be required to bore an inch hole; and though these hollow edged bits are not so well adapted to continuance of grinding as plain ones, yet make full amends by their much less frequently wanting sharpening. How far this kind of bit may be adapted to gun boring, I leave to your trial.

Austhorpe, January 9, 1779. J. SMEATON.

EXPLANATION OF THE SKETCH,

Shewing the manner of applying the inclined Plane for releasing the Work of the discharging Apparatus for the Carronades.

Fig. 2 shews the same face of the work as is shewn in fig. 2 of the design for the discharging apparatus sent before, wherein E F G is the discharging arm, and V W is an upright piece of wood capable of sliding up and down, but in no other direction, and the same letters denote the same thing in the side view thereof, fig. 1, to which is attached or made out of the same solid X Y Z, the inclined plane or wedge. In the present position of it, it is in a posture for acting upon the discharging arm, and is kept up by means of the catch *m n* dropping into a notch under the piece of iron at O, when the arm E comes into the position *e*; it then begins to touch upon the inclined face X Y, and, going forwards, by degrees gets discharged before it comes to the position *p*, which shews it discharged and resting upon the pin *q*, where it remains till the gun is shifted, and the rotation is wanted to be commenced; then the catch *m n* is drawn back by a cord, which lets the piece V W drop, till the line X *e* goes down to the line *q r*, viz. about 16½ inches, which entirely clears the discharging arm, and then its own spring brings it into its working position, where the next time the revolving arm meets it, takes it along with it, and the motion will be continued till the piece V W is drawn up again by a cord, lever, or other equivalent contrivance, till it is supported by the catch *m n*, when at the first meeting it will be discharged as before.

Austhorpe, January 9, 1779. J. SMEATON.

Explanation of the Design for turning Shot Moulds.

The semicircle A B C, fig. 1st, is supposed to be the horizontal section of a half mould, seen from above, which, together with C *a b c d e f g h* A, is supposed to complete the whole of the section, and is supposed to be properly fixed upon the arbour or mandrel of a stout chock lathe, capable of turning it with steadiness.

D is the centre of the sphere, and, upon an axis passing perpendicularly through this centre a frame is supposed to turn, that carries the tool, so as to describe the quadrant A B, and by that means the semicircle A B C; *i k l m* is the upper surface of the cutting-tool, *l m* being the cutting-edge. Now, if the edge *l m* be formed into an arch of a circle, whose radius is less than the sphere to be described, and whose centre (suppose at *n*) is capable by the inclination of the frame to be brought into the radius line A D, then it is evident, that if, while the mould *f c d e* turns round its axis D B, the tool, by gradual inclination of its frame, passes from A to B, the tool will cut off all superfluous matters that projected beyond its sweep, and also in case the cutting-edge of the tool is regulated to a just height, so as to pass through the centre of motion of the mould at B, then it is plain that the hollow figure thus described must be an exact hemisphere.

Nothing can be more evident and simple than this proposition; the whole difficulty consists in having those exact adjustments that are requisite to perform the necessary conditions, and, at the same time, all the strength and steadiness in the framing that is necessary to work upon and cut clean a mass of cast-iron; for this purpose

E F is a section of one cheek, and G H that of the other, of a mortice through the solid metal, for lodging the tool *i k l m*, and the prolongation G K is for the reception of a hollow wooden handle, sufficiently long for turning the frame steadily round upon its axis, while the cutting-edge of the tool is describing the quadrant A B.

Fig. 2 shews an upright section of the mould, wherein the same letters denote the same things as in the former figure, *i m* now shewing the upright of the tool, whose cutting-edge is at *m*; this is pushed towards its work by the screw *o p*, which passes through the stud I, affixed to the projecting part G K, and the tool is tightly held down in its mortice or socket by L M, a wedge, which last is slacked or drawn out by *q*, a counter wedge. The socket G H, the prolongation or tail G K, are cast in one solid piece with N O, the upright axis, and those with the projecting ears Q Q, which are supported by and turned round upon the points of the screws R S, by which means the frame is made capable of turning round upon the line R C D A S, passing through the centre of the hemisphere A B C, at the same time that the frame will clear the face of the mould when in its most inclined position, as is shewn in fig. 1; where observe, that the dotted square G N shews the section of the upright axis above and below the socket, as at N and O, fig. 2, and the dotted space G N Q, fig. 1, shews the figure or plan of the ears at top and bottom, where they engage with the points of the screws R and S.

Fig. 3 shews the fore front of the mould in the lathe, and the same letters will denote the same matters, besides which T V W X Y *Z*, &c. denotes a strong frame that surrounds the whole mould, and supports the screws R S upon which the upright movable turns upon as a centre, as already described, which outward frame is to be firmly bolted down upon its flat base upon a stout plank, which plank is to be made to slide with ease and certainty between the cheeks of the lathe, so as to move in a line parallel to the axis of the mandrel, and to fix at any distance

required from the end of the mandrel. It is also supposed, that the axis of the mandrel is adjusted as nearly as possible to a parallelism with the cheeks and platform of the lathe.

Now the first necessary condition and adjustment is, that the height of the cutting-edge of the tool shall exactly pass through the centre of motion of the mould, which will best be done by trial, because if it leaves no extuberance in the centre, it is plain it has passed through it; if an extuberance is left, it must be by passing either above or below it, and which of them it is may be seen, and the moving frame set higher or lower, by slacking one and tightening the other of the screws R S, and repeating the trial till the surface is left without an extuberance in the centre.

The second necessary condition and adjustment is, that the line joining the points of the screws R S shall pass through D, the centre of the sphere, that is, through the axis of the mandrel produced, which will also be best known by trial; for this purpose, let a gage circle be turned from thin plate brass to the intended diameter of the ball or sphere of the mould; turn out also the central part of the area, leaving it a ring about $\frac{3}{4}$ or $\frac{5}{8}$ of an inch broad, and cut this in two, which will thereby make two gages: thus provided, let a sweep be made for trial, and it will be known by the gages fitting the sweeped surface whether the cutting-edge of the tool is at its proper distance from the centre, because then the gage will fit the sweeped surface when directed towards the centre; if not, let the tool be set forward by the screw *o p*, till they perfectly agree, then running the gage through the centre and *beyond* it, if the gage bites hard upon the further quadrant, then the axis of R S is beyond the axis of the mandrel; but if the matter beyond the centre leaves the gage, then it is plain that the axis of R S is on the side of the axis of the mandrel that was the cutting side of the mould, and, accordingly, this is corrected by slacking the screw *r r*, and tightening the screw *t t*, or the contrary, till a sweep being taken, the gage every where applies itself to the hollow surface of the mould; and this adjustment being once performed, there is nothing but gradual wear or violence to put it out again, and the gage being applied to every mould, it will always be seen whether any apparent error gradually arises.

The screw *r r* acts upon the stud S, and the screw *t t* upon the stud V, both of which are cast upon the same piece of metal with T V, which carries the screw R, and slides sideway in a chamfered groove in the upper bar of the outward frame, as is more particularly seen in fig. 2. I have described the same kind of slide at the bottom Z S, &c. but this is scarcely necessary; for, if the whole frame is bolted down upon the sliding plank, so that the line R S may originally be nearly right, when T V is in the middle, the adjustment may be sufficiently performed by sliding the screw R only; for it is no ways requisite that the line R S should be exactly perpendicular, but only that it passes exactly through the axis of the mandrel produced; but it will be necessary that both the screws R and S should have a counter nut, as at the dotted lines *w w* and *x x*, unless they are made to screw stiffly through their carriage-pieces.

It is to be observed that, on changing the size of the mould, there ought to be nothing wanting in the way of adjustment, but to set the cutting-edge of the tool to its just distance from the centre; and as the tool changes in its height by grinding, or a different tool, to see that it passes through the centre, that is, supposing the slide of the plank duly performed; and, as upon this slide being correctly performed, a great deal of the ease and facility of the use of this machine will depend; and as this correctness may seem difficult to arrive at, I will take occasion to make an

observation upon lathe-making, which may apply itself to several other things in the Carron works. To make the heads, &c. of a lathe to slide in a right line between the two parallel cheeks with ease and facility, and without vacillation or shaking, is in reality no easy matter to perform; but if the near upright face of the further cheek is shot true and straight with a plane, and the upper face or platform of the two cheeks shot straight and flat, that is, out of winding, all which in carpentry is an easy proposition; if then all the matter composing the seat of the heads is cut away or hollowed off, except about the value of $1\frac{1}{2}$ or 2 inches square, at the four corners, and these prominences brought to a just flat, so as to fit true without shake upon the platform of the lathe; if, also, the far side of the tenant is made to take its bearings at the outsides, so as to apply itself fairly and steadily to the far cheek of the lathe; then, if the heads (or any other sliding piece formed in this way) are pushed home against the far cheek with one hand, at the same time that the wedge or screw is tightened by the other, it is plain that these heads or sliders will obey the same right lines that form the upright face of the back cheek and platform, and it is then no matter whether the tenant fills the groove or not, but when slacked will be always at perfect liberty. It seems hardly needful to say, that for correct work the cheeks of a lathe should not only be made of dry seasoned wood, but clean and free from cross baits, to prevent their warping after made.

N.B. I am not well acquainted how well the Carron metal works with a file, but, to avoid all intricacy and trouble in forging, I would choose the work to be cast of gun-metal, or, perhaps, what may be better, 1 ounce of tin to 1lb. of copper.

The mould being supposed hollowed to a true sphere, but a little too deep, then there will be nothing to do but to turn down the face of the rabbat *h* A C *a*, till the depth D B is exactly half of the width A C, and then two such will form a sphere.

It is plain from the figure, that to give the tool a proper bearing in its socket, that one upright frame will not do for all sizes; the present one is drawn at large to answer any size, from a 24lb. shot to a 9lb.; another one will go from that to a 3lb.; under which, it will be proper to have one of a proportionable size; but they will all apply themselves to the screws R S, and without any other adjustment than that of height. I must, however, observe that the screws R and S, must, in proportion to their size, be cut with a fine thread and with sharp stocks, that being first truly turned, they may not cast in stocking, so that when turned round in their sockets, their centres will not sensibly vary. This is a matter requiring attention, but being duly attended to, is not difficult to be practically performed.

Austhorpe, Jan. 16, 1779. J. SMEATON.

EXPLANATION

Of two Methods of Raising the Slide Carriages for the Carronades.

Fig. 1. A B represents the slide carriage plank.

C D, a piece of wood bolted on crossways upon the under side; this transverse piece is pierced towards each end by a female screw, capable of receiving a male screw, one of which is denoted by

E F, a wood screw 10 inches long in the screwed part, and 2 inches long in the head part F, which is well bound with an iron hoop, and perforated crossways with a

couple of holes for small handspikes. The position here shewn of the slide plank, is horizontal, or parallel to the deck, which, according to the sketch sent, its under side in that position was 12 inches, and in this position the part of the screw shewn clear, viz. F G, is 4 inches; so that when the head F comes close to the transverse piece C D, the end A will be lowered 4 inches, and then the top of the screw will just reach to the upper surface of the slide plank, but without reaching through, so that the hole cut through it to clear the screw, may be covered with a thin plate if thought necessary; but, if the screw is unscrewed 4 inches more than is shewn in this position of the figure, so that the top of the screw E will come down to H, then the end A will be raised 4 inches higher, and yet the screw will have 2 inches hold of the box, which, containing three threads, will be sufficient to keep it steady.

Fig. 2. A B represents the slide carriage plank as before; C D shews one of two planks, bolted edgeways under the carriage plank, cut into 6 steps *a b c d e f*, each 1 inch in height, and 2 inches in breadth.

E F shews a piece of wood seen endways, long enough to take both the stepped planks, and stepped also into 6 steps, *g h i k l m*. Now, if the height of the lowest step *g* is 4 inches, and increase by 1 inch, then it is evident, if this stepped wood is drawn gradually back, the plank A will descend 1 inch at a time, till the step *g* comes under the step *e*, and the step *h* under the step *f*; then will the end A have desended 4 inches: but if from the present position the stepped wood is pushed in one step at a time, then the end A will rise accordingly, till the step *m* being under the step *b*, and the step *l* under the step *a*, so that the plank A, or rather the point *a*, will be raised 4 inches; and if it is thought expedient to keep them from jumping out of their places, the small staples *n o* being struck in at each end, and the parts lashed together with a marline, this will be sufficient to keep them from shifting the steps upon a discharge, as I apprehend.

Austhorpe, Jan. 20, 1779. J. SMEATON.

EXPLANATION

Of the Design for a new Nose-pipe for Carron.

Fig. 1. A B is supposed to represent the fire-stone that now makes the tuire of the furnace, which is supposed to be of the accustomed thickness, but perforated with a round hole of 7 inches diameter, or of such other width as it may be thought proper first to try.

C D E F shews the horizontal section of an iron tube serving for the nose-pipe, also of 7 inches diameter, and checked into the stone, and the joint made good with fire-clay, which round tube branches out sideways into

C G H and D I K, which are the sections of two oval tubes, whose axes M L and N L, meet the axis of the main tube at L.

O P Q R represent two dove-tailed sliders, that shut up the orifices of the oval side tubes, so as to be air-tight; those oval openings are proposed to be 4 inches wide by 6 inches high, so that on removal of the sliders every part of the opening of the tuire into the furnace may be seen, and the arm and instruments introduced by which it may occasionally be luted, and when shut, the wind will take its course from the part of the tube E F, towards C D, in a parallel direction.

N.B. About 8 or 10 inches of the external part E F, is proposed to be kept of a width, but from thence to increase gradually tapering to the size of the main conveyance-pipe.

Fig. 2. represents an upright section of the main tube at the line S T, upon fig. 1.

E F is the main tube.

O P shews the oval hole with the slider drawn out.

Q R represents the slider in its place, wherein, if thought convenient, *v w* in both figures represents a hole, whereto a piece of plate glass being adapted, and fixed in each slider, the condition of the tuire may, at all times, be inspected, without drawing the sliders, or disturbing the blast.

Austhorpe, May 2, 1779. J. SMEATON.

A Comparative View of the State of the Carron Furnaces in October 1776, *and in September* 1778.

	No.	Gate drawn.	Head of water.	Diameter of nose-pipe.	Number of cylinders.	Cube feet of air per minute.	Velocity per second.	Tons of water expended per 24 hours.
State of Furnaces, October, 1776.	1			2¼	28	1571	947	16,502
	2			2½	24½	1708	835	16,047
	3			2 7/16	19	1343	691	15,732
	4			2¼	12½	1459	881	17,769
					Sums	6081	3354	66,050
					Means	1520	838	
			ft. in.					
State of Furnaces, September, 1778.	1	1¼	3 7	2¼	25	1402	846	16,322
	2	0⅞	4 8¼	2½	16	1116	546	11,724
	3	1⅛	3 10½	2 7/16	17½	1237	562	15,286
	4	0¾	3 0½	2¾	20½	1309	529	7,396
	6	0⅝	3 1¾	2¾	21	1341	542	6,630
					Sums	6405	3025	57,358
					Means	1281	605	

From the preceding table there appears a great improvement in the dispensing of the water, for in the year 1776 four furnaces expended 66,000 tons per 24 hours, and in the year 1778 five furnaces expended but 57,300.

It is, however, remarkable, that of the last-mentioned quantity, numbers 1 and 3 expended 31,608 tons per 24 hours, while the other three furnaces expended but 25,750, the cause of which disparity it may be proper to inquire; for though every degree of accuracy, I doubt not, has been exerted in the new building of No. 6, and the rebuilding of No. 4, yet there is not that difference in the principle of action that can make these two machines so very much exceed those of Nos. 1 and 3; for in point of construction I should not expect them to fall short of the performance of Nos. 4 and 6 more than 20 per cent. This difference I must, therefore, attribute in a great measure to the different widths of the nose-pipes, which, as I have never heard of their being varied, I take for granted they continue the same they were in the year 1776, that is, as I have put them down. And I have no doubt but that if they, as well as No. 2 were furnished with the same kind of nose-pipes, that Nos. 4

and 6 blow with, that they would then perform within a reasonable difference of those last furnaces; if not, the rest of the difference must be sought for elsewhere, that is, either in the untruth of the cylinders, too great friction of the leathers, a straightening of the wind passages, or a general disrepair of the machines; all which are matters well worth looking into; for if two furnaces can be worked with 14,026 tons per day, this is less than the average quantity for each of the other three, which is 14,444.

Again, although it appears that the expenditure of No. 2 is greatly reduced, owing in part to the removal of Mr. DOWNING's incumbrances, and in part to the reduction of the number of the cylinders per minute (which I suppose was also a consequence of the restitution), yet, if the expenditure of No. 2, viz., 11,724 tons per day, be reduced in proportion of 23 to 20 (which would certainly be the case if that wheel was raised to 23 feet high, like Nos. 4 and 6), it would still expend 10,195 tons, which is 2799 tons per day more than that of No. 4; and as there does not appear to me any other thing in the construction of the machine No. 2 that should make it fall short of No. 4, this extra expenditure by No. 2 remains to be accounted for, and which in part I doubt not is owing to the difference in its nose-pipe.

That the difference of the friction of the leathers is capable of considerably varying the expenditure of the water, I think, appears pretty plain from Nos. 4 and 6, the former consuming more water by 11½ per cent upon the lesser quantity, than the latter does; and, therefore, as they are both as nearly alike as possible, the No. 4 being the last built furnace, it seems most probable, that the sides of its cylinders were not at that time got to so great a smoothness as those of No. 6, or that casually No. 4 was at that time harder in its leathers.

Now, if we suppose Nos. 1 and 3 to be reformed so as to perform within 20 per cent of No. 4, and No. 2 reformed so as to perform as well as No. 4, then the expenditures will stand as follows, viz.:

No. 1....8875	No. 4....7396
No. 2....7396	No. 6....6630
No. 3....8875	39,172

From this statement it appears probable, that the consumption of all the five furnaces may be reduced to 39,172 tons per 24 hours; and as Carron furnishes in dry seasons 26,400 tons (see report of 6th April, 1777), there will then only remain 12,772 tons per 24 hours to be provided for out of the reservoirs; and as it is stated in the same report that the home reservoirs alone contain, upon three feet depth to be drawn off, a treasury of 164,268 tons, this would supply *five* furnaces at the rate above stated for near upon 13 days; whereas the same quantity, according to the view of the subject at that time, was not likely to serve *four* furnaces much above 7 days. But, further, in case No. 1 or No. 3 were laid off in times of scarcity, or that they both together were allowed but 8875 tons per day to keep them alive, then there would be only 3897 tons per day to be provided for out of the reservoirs, which would last the furnaces at this allowance full six weeks, which together with the other command of water the company already have, seems to render the building a fire-engine of any construction totally unnecessary, especially if the old engine is kept in working order to serve an emergence.

For some time No. 1 led the van of all the works, now it is got into the rear of all; but if you had an opportunity of applying the nose-pipe I transmitted in my letter of the 13th ult. I have reasonable expectation that this furnace would once more lead the van.

AUSTHORPE, June 11, 1779. J. SMEATON.

THE REPORT

Of JOHN SMEATON, *Engineer, concerning the Expediency of opening the temporary Cut and Lock near Dalderse from the Canal of Forth and Clyde to the River Carron.*

THE utility of this cut, from Carron shore and parts adjacent, appears from its first construction,which was to bring the stones got from the quarries at and near Kinnaird, and brought down by the coal wagons to Carron shore, there put on board small lighters, was brought through the temporary cut, and brought to build the first land lock, and other works in that quarter; also the lime, pozzelana, and timber were brought for some time that way; and it being a work ordered by the Committee, principally by the advice of Mr. MACKELL, he urged in favour of its expediency, that it would be the properest accommodation to the Carron works, and that (in his way of expressing himself) that Company should never get any other. From this it will appear (which I perfectly remember) what were Mr. MACKELL's sentiments concerning it at that time. On examining it, which, at the request of the Carron Company, I did the 6th of November last, I found both the cut and lock to all appearance in much better condition than I expected; the principal thing wanted to restore it, will be a little more room, to get earth to strengthen and heighten the banks, equivalent to those of the main canal; and respecting the lock, for any thing that appears, it seems to be likely to want little for some time to come, more than new gates; and the lock is of so small a size, that the head of the lock may be shut by a single gate, in such a way as to occasion much less leakage than the larger pointed gates, and in a mode that I first put in practice upon the river Calder, in or about the year 1761, and which the last December, I had the pleasure to see in perfect good order, without having had any derangement or repair.

The constant leakage being in this manner secured to all small vessels having a right to pass the canal proceeding singly upwards, as much water will be saved to the last, or sea reach, as is equal to the difference of area between the temporary lock and the canal locks, which is much more than double, and will be more than equivalent to the consumpt of such vessels as may happen to have occasion to go downwards, from the temporary cut; besides, as this reach is of a considerable length, and pretty capacious, and naturally receives the regulating water, and all the leakages from above, there is the least fear of wanting water in this than any other of the reaches.

I remember myself that this accommodation was frequently mentioned as proper for the Carron Company, but which at that time they did not think sufficiently commodious, and near their works.

As, therefore, it appears likely, that by opening this temporary cut and lock, there will be a considerable increase of freight and tolls, without any loss, that it will, for the advantage of the whole, be a proper measure to be carried into execution.

AUSTHORPE, February 7, 1782. J. SMEATON.

N.B. I apprehend that small vessels will generally pass single, for it is to avoid waiting for freight that larger vessels are not used.

TO THE CARRON COMPANY.

GENTLEMEN,

It is from what has occurred to me in the experience of 30 years in the profession of civil engineery, that I have long entertained an idea that cast-iron anchors, I mean those of the largest sizes, would be found of equal if not superior strength to those of wrought-iron; and though, in a case where not only the lives of men, but the welfare of nations is concerned, no mercantile consideration ought to take place, nor ought any thing to be spared that can add to the perfection of so very material a utensil as that of the anchor; yet if, upon a fair and full trial, it shall appear that cast-iron ones, of a proper composition of metal, are, in reality, equally or preferably to be depended upon, then the readiness, cheapness, and facility, wherewith they are to be produced, appear to me a very sufficient reason (to say nothing of the encouragement of a British, in contradistinction to a foreign, production) why such a fair and full trial should be made as shall be sufficient to put the matter beyond a doubt.

I never supposed that any kind of cast-iron would be equal in bearing a stress with that of wrought-iron, even of a tolerable quality, provided the size and shape of the matter to be formed of wrought-iron is capable of being firmly welded and united in one solid mass: for this reason, I cannot suppose any anchor can be formed of cast-iron, that shall bear a stress equal with one of wrought metal, whose shank is in the smallest part not more than 3 inches, or $3\frac{1}{2}$ inches in diameter: but observing in such large anchors for first and second rate ships of war, as I have had the opportunity of seeing when broken, that the wrought bars of which they are composed are very imperfectly welded and united together in the inside; and having also experienced, on the other hand, the very great strain that large masses of well-mixed cast-iron will bear, when applied to the greatest stresses in mill and engine work, I have been naturally led to put the query, whether beyond some certain medium, that is, whether in those very large and heavy anchors for the largest ships, the substitution of cast-iron, instead of wrought, may not be in every respect useful and advantageous?

Had the trial you have communicated to me, made by the officers of his Majesty's yard at Deptford, appeared to me conclusive, I should have there rested the matter with them, as fully and sufficiently tried; but with all due deference to those gentlemen, whose knowledge in their profession entitles them to the greatest respect from the public, I beg leave to say, that this is a new case, and, therefore, till it is tried, in a manner similar to that in which it is to be used, it is in fact no trial at all.

Had the proposition been to try whether a wrought or a cast-iron anchor, or indeed a bar of metal of any size, would best bear the blows of an iron ram or beetle, the mode of trial was perfectly adapted to prove the point; and I am so far satisfied of the fact, as it turned out, that I even wonder that the palms were not broken by the hammers; but I conceive there is nothing like the collision of hard bodies in the real use of an anchor at sea; on the contrary, no stress can possibly be communicated more kindly than that of a ship to its anchor, through the intervention of a long cable. It is possible, in letting go an anchor, it may fall upon a rock, but I conceive an anchor is never let go in foul ground by design, and by choice, but yet it may happen and be necessary. The anchor in its descent having necessarily the cable to haul out after it, and the stock of the anchor, like the log, to haul crossways through the water, the velocity natural to the descent of heavy bodies is hindered from taking place in so great a degree, that let the water be ever so deep, the velocity

wherewith it strikes the ground is very moderate, and with this further circumstance that must attend it, that, from the anchor-stock and cable both conspiring to act as a rudder, the anchor will necessarily fall with its shank near a perpendicular direction, and, therefore, have the best chance of impinging upon some part of the crown that is fortified in the best manner to resist blows, as well as every other violence: besides, the rocks below the surface of the sea, being supposed a continuation of the strata above it, and nearly of the same hardness, they are, comparative to iron, generally soft bodies, and the hardest of them all that lie in masses in this kingdom, that we know of, would, by such a stroke, be *bruised*, less or more; and this is certain, that the effect of a stroke, where either of the bodies is bruised, or will rebound by elasticity, is widely different from what will happen when neither of them will give way in a sensible degree; I must, therefore, conclude, that there is not, nor can be, any thing in the real use of an anchor that is in any degree analogous to the stroke of an iron ram, much less to such a stroke applied crossways upon its shank.

The windmill, axis, and oil-press, that you cast for me the year before the last, the former has withstood the fury of all the storms that have happened since, without the least likelihood of injury; and yet one blow of the Deptford piling-ram, properly directed, would destroy it. The oil-press is in constant work, and every five or six minutes is subject to an alternate pressure and release from it equivalent to 300 tons of dead weight, tending directly to rend it in two; and yet, I believe, a single well-directed blow of a sledge-hammer would break it. If the length of time of the use of these utensils is not thought sufficient, I must add, that in the year 1755, that is, 27 years ago, for the first time, I applied them as totally new subjects, and the cry then was, that if the strongest timbers are not able for any great length of time to resist the action of the powers, what must happen from the brittleness of cast-iron? It is sufficient to say, that not only those very pieces of cast work are still in work, but that the good effect has, in the north of England, where first applied, drawn them into common use, and I never heard of any one failing. Your own method of breaking up the largest iron guns is also an example to the same purpose, where the blow arising from the fall of an iron ball of 7 or 8 cwt. produces an effect that ten times the power of gunpowder would not; for the action of powder, though very quick, yet differs from the instantaneous action of a blow, in much the like manner as a line does from a surface.

The mode of trial that would appear to me conclusive would be as follows: I would take two anchors, as nearly of a weight and dimensions as possible, the one of wrought, the other of cast-iron, not less than three tons weight each (two tons I think too much in favour of the wrought-iron for a *first trial*), and placing them at a competent distance in a right line, with the rings towards each other, for each I would dig a pit in the firm ground, capable of burying both the palms of each anchor: at the bottom of each pit I would fix, edgeways upward, a large elm plank of 10 inches or a foot thick, into the middle of which I would make a moderate perforation of about 3 inches, to receive the point of the fluke of each anchor; these planks I would guard with piles in the securest manner possible, to prevent them, on the application of a great pressure, from moving towards each other, and then well ramming up the whole with earth, so as to bury the anchor, the shanks of each to be inclined upwards, so that the rings may be at or near the surface.

Then having provided two pair of purchase-blocks capable of purchasing 15 or 20 tons each, with suitable tackle-falls, and cap-stands, crabs, or tooth and wheel gins, I would hook one block of each pair to the ring of one anchor, and the other to the other, securing every thing as much as possible; and the tackle-falls being made to

go off to the cap-stands, each by a snatch-block sideways, it is plain, that whatever strain is upon one anchor, the same will be on the other; I would then proceed to heave till something gave way, and whichever of them kept the ground, after the other, by failure, was drawn out of it, would be the anchor upon which I should be ready, in case of the greatest extremities, to pin my faith.

The expense of the trial I should think no object, for in case the cast-iron anchor was broke, and the other unhurt, there would be no loss but of a little labour; and was I to go to sea, I should choose the anchor that had been so severely tried, in preference of all others of the same size and kind: but if the wrought-iron one gave way, by binding or breaking, so as to quit the ground, while the cast-iron one remained unhurt, then a discovery will result worth the price of 20 anchors.

In this manner, if the cast-iron anchor proved the conqueror, I would proceed to try those of a lesser weight, so as to find somewhat nearly the medium, at which the wrought-iron anchor would have the preference, keeping always on the safe side of the question.

These, gentlemen, after full consideration, are the result of my genuine sentiments of this subject, which you have desired; and if found useful towards determining a point that may be of much utility to the public service, shall think my pains and study well employed, and remain,

Gentlemen,

With much esteem and respect,

Your most humble servant,

Austhorpe, February, 7, 1782. J. SMEATON.

LONDON BRIDGE.

The Report of John Smeaton, upon the Questions proposed to him by the Committee for improving, widening, and enlarging London Bridge.

Question 1st.—In what degree, at a monthly average, is the natural power of the water, and effect thereof, upon the wheels of London Bridge water-works diminished, by removal of the pier, and opening of the great arch?

Answer.—By calculation it appears, that the natural power of the water, as the circumstances of the great arch were in the beginning of February 1763, was diminished at the monthly average as 2000 to 1277; and that the effect thereof upon the wheels, as appears by the company's register, for above six years past, was diminished in proportion of 2000 to 1300. The process of which investigation is hereto annexed.

Question 2d.—What are the methods whereby the effect of these works may be restored to the same quantity, with respect to raising water, as subsisted before the opening of the great arch?

Answer.—The methods that can be put in practice, for restoring the effect of the works, are reducible to two, viz. by improving and enlarging the present works, or by penning up the same head of water as before the alteration. With respect to the present wheels, though they are all capable of improvement, yet they cannot all be improved in the same degree in which they are now deficient, nor can they be so

much improved taken collectively; it will, therefore, be necessary, not only to improve some of the present wheels, but to add a new one; but as the old wheels cannot be much improved without rebuilding, and *one* new one cannot be depended upon to make good the deficiency, without rebuilding some of the old ones; as the power, while acting, must be increased, in order to do the same business in a less time, and as the present mains are but barely adequate to the present wheels, (which appears from their refusing a part of the water thrown up by the engines during the action of the strong spring tide, as has happened during my examination of the works), it follows, that the addition of wheels will require an addition of mains, which, upon the whole, will create a great expense, and of a very complex nature. On the other hand, the very same expedient that will be necessary for securing the great arch, will also contribute considerably towards the relief of the water-works; I, therefore, think it more eligible for the committee not to engage in building or improving the water-works, but to proceed to such method as will restore the head of water; which may be done, as I conceive, at a less expense, and not only without prejudice to the navigation, but in some respects be an aid thereto; and that is, by raising the bed of the great lock, and some others, that are unnecessarily deep, and by stopping the water-way below the starling of two others, which appear to be of little or no use or consequence to navigation.

Question 3d.—If by stopping up arches, or raising the bed of the river under the arches, which arches will be best to be stopped up, or the beds under them raised; and what will be the expense thereof?

Answer.—The addition of water-way is altogether made under the great arch; and if the reduction were to take place there alone, it would totally defeat the purposes of the committee in doing service to the navigation, by the opening thereof; it is, therefore, I propose to do only a part here, such as is consistent with those views, and the rest under such arches as will admit thereof without prejudice.

For the particular manner of executing this scheme, I must refer to a drawing (see plate 1), containing two sections of the water-way under London Bridge, the first figure shewing the water-way as it was before the alteration; and afterwards, as it was at the beginning of February 1763; figure 2d shews the water-way as it is intended to be after the alteration now proposed.

The abstract of the first section, figure 1, is as follows:

	Feet superficial.	
The area of the water-way below the starlings, before the alteration, was		2073
The increase of water-way by removing the solid under the great arch, and by the subsequent increase of depth	861	
The diminution of water-way by stopping up the two locks next the south shore	154	
The difference is the increase of water-way.....		707
The sum is the water-way after the alteration, the beginning of February 1763		2780

It therefore appears, that in order to restore the water-way, and of consequence the water-works, to what they were before the alteration of the great arch, the area of the water-way below the starlings, such as it was the beginning of February 1763, must be reduced by 707 superficial feet; and in order to do this without prejudice to the navigation, I would propose, 1st, to raise the bed of the river under the great arch, so as to be eleven feet at its highest part under the top of the starlings, in which case it will have the same depth of water as the draw lock, which was accounted the most useful for large craft before the alteration; and which, as well

as the great lock when the water-way is restored, will never have a less depth of water than five feet at low water.

2dly. By advancing the starlings into the great lock, so as to double the fence, as proposed to the committee by Mr. PHILLIPS, a further reduction will be effected; and this being done three feet on each side, will still leave a water-way under the great arch, in breadth fifty-two feet, which will be very sufficient for the craft.

3dly. I find there are four locks, whose depths exceed that of the draw lock, all of which are, on account of their widths, unfit for the passage of the larger craft. I therefore propose to raise the beds of those locks one foot higher than the level of the draw lock and the great lock. St. Mary's lock was justly accounted the best for large craft before the alteration, being the widest (viz. nineteen feet in the clear) and one of the deepest (viz. fifteen feet below the starling), that is, four feet deeper than the draw lock; this depth of fifteen feet I apprehend to be totally unnecessary, and rather tending towards the insecurity of the bridge; but, as the preserving one lock deeper than the rest, may possibly on some occasion be useful, I propose raising the bed of St. Mary's only two feet; in which case it will be thirteen feet below the starlings, that is, two feet deeper than what is proposed for the great lock.

4th. As Long Entry and Chappel locks, which lie between St. Mary's and the great arch, appear to be of less use than any of the rest, being both narrow and shallow, and by their indraft tend to bring the craft foul upon the intermediate starlings, without a possibility of their passage, I would, therefore, propose those to be stopped up to starlings' height, the same as the first and second locks on the south side now are: and that the craft may not be entangled with those locks or their starlings, but always find a passage either through the great lock or St. Mary's, I would propose fender piles to be drove at about three feet distance in a circular manner, from the upstream point of the starling of the great arch, to the upstream point of the starling of St. Mary's, as represented in the draft fig. 3, at R.; those piles to be well braced, and their heads capped over about two feet above high-water mark.

These things thus done, the account will stand as follows:

Proposed Reductions of the Area of the Water-Way below the Starlings.

	Feet, superficial.
By raising the bed of the great arch	314
By extending the starlings three feet on each side	66
By raising the bed of little lock	52½
By ditto of St. Mary's	38
By shutting up Chappel lock	50
By ditto Long Entry	66½
By raising the bed of Nonsuch lock	60
By ditto of Roget lock	27
By ditto of the fifth lock	37½
Water-way to be reduced	711½
Increase of water-way as before stated ..	707
Overplus	4½

Now, there will still remain an increase of water-way above the starlings by the removal of the shaft of the middle pier; but, as the effect of this can only take place while the water is above the starlings, when the water-way is at the greatest, the effect upon the water-wheels thence arising does not appear by computation to be

above $\frac{1}{360}$ part of the whole, which will be much more than compensated by the above overplus of $4\frac{1}{2}$ feet below the starlings.

It is possible, notwithstanding the attention I have paid to this matter, that some circumstances may intervene, which have not occurred to my consideration; but I apprehend that none can, which may not be compensated by raising the bed of St. Mary's lock to the same height as the great lock; to which I can see no objection, if experience should shew the same to be necessary.

The easiest, cheapest, and most effectual method of raising the beds, not only of the great lock, but of the others, is, by throwing in rough stones, so as to form a slope both ways, the interstices of which in time will fill up with gravel and the fullage of the river, and become as compact and durable as a rock. The heaviest, roughest, and largest stuff, is best adapted for this purpose, and none better than large Kentish rubble; but for want of a sufficient quantity thereof, Portland or Purbeck rubble may be used, provided it is more large in proportion as it is less sharp and heavy. For the particular application thereof to the great arch, I refer to the drafts, figs. 4 and 5.

N.B. If the following method should be thought more eligible; instead of raising the bed of St. Mary's lock, the first open lock next the water-works may be stopped up, by two pair of gates pointed westward; forming a navigable pen lock between them; which would enable such craft as can row or sail against tide to pass the bridge upward on tide of ebb, without waiting for tide of flood. And in this case the stopping up of Chappel and Long Entry locks may be dispensed with. In what extent this scheme may be of advantage to the navigation, I am not enabled to judge, but am of opinion, that if not of material use, what was first laid down is the most eligible, as the gates would need frequent repairs.

Question 4th.—If by improving the old wheels, or adding new ones, which will it be best to improve, or where add the new ones; and at what expense will this be done?

Answer.—I apprehend, as was mentioned before, that all the wheels may be improved, but the wheels in the first and fourth arches from the north shore are the most susceptible thereof, and the most want it; if any wheel were to be added, it should, undoubtedly, be in the fifth arch, which, though a capacious lock, is not much used by craft going down on tide of ebb, on account of the shipping commonly lying before it; but as I look upon it to be more eligible to restore the effect of the water-works by the more certain, and, perhaps, less controvertible, method above described; I have not made estimates for these erections and improvements, to do which, with any tolerable degree of exactness (being very compounded), would take up some time.

Question 5th.—If arches are stopped up, or beds raised, what effect will this have upon the channel of the river?

Answer.—If done in the manner before proposed, no sensible effect of any kind whatever.

Question 6th.—What effect upon the channel of the river has been produced by opening of the great arch, and by what means are the inconveniences, if any, to be removed, and particularly with respect to what is alleged in the memorial of the Watermen's Company?

Answer.—Upon opening the great arch, the water finding a more free and open passage there than in any other part of the bridge, the main current would, of course, be drawn thither, and in consequence, acting more strongly upon the bed of the river than before, some thousand tons of matter appear to have been moved by the action

of the tides setting in each way, above, between, and below the starlings; the most gross and heavy parts subsiding as soon as the strength of the stream is spent, form shoals or banks of matter both above and below bridge; yet such banks, though increased by the fresh action of the great arch, appear, in a great measure, to have been formed before, by the rapidity of the current setting through the arches; and I remember to have seen the shoal above bridge many times dry before the alteration took place, and, if I am not mistaken, that below likewise. The present channel below bridge, stands quite fair to the great arch, and has about 4½ feet navigable water over it at low still water; but above bridge the case has been more untoward, for the body of the former shoal happening to lie somewhat to the south of the direction of the great lock, the new-formed matter has, in a great measure, lodged itself in addition to the north side thereof, which has of consequence thrown the main channel of the river considerably more to the north side, so that the current, on tide of ebb, making a sudden turn near the bridge, has rendered it difficult for the craft to make the great arch, notwithstanding the great enlargement of its width. The effect of this grievance will, in some measure, be remedied by the alterations proposed in the bridge itself, because the set of the tide being less strong to the great arch, as well as more equally all over the bridge, the direction of the current will be less diverted towards any particular place; towards this end the stoppage of Long Entry and Chappel locks will also contribute; for being situated between two of the principal arches, the balance will be preserved, and the current less diverted in its passage through either of them. This, together with the fender piles before these two locks, will direct the craft, so that they cannot fail of hitting one or the other, when there is water enough over the shoal above; but at or near low water, I do not apprehend that any thing less than taking the whole shoal away, down to the depth of the main channel, can procure a true set of the tide; however, it may in a great measure be remedied, by making a passage or channel through the shoal, which channel, to prevent as much as possible the effect of the superior indraught of the main channel from acting upon it, should be exactly in the direction of the great arch, but its west end declining a little to the southward: this new channel should be at least 4 feet deep at low water, and as wide as the great arch, and I know no better method of performing it, than by the ballast lighters; it will also be advisable to widen and deepen the present channel through the shoal below bridge, so as to make 2½ feet more water over the same, but this will be a much less work than the former.

I come now to consider the matter of the memorial of the Watermen's Company.

I apprehend, when all is finished, the great lock will be found most useful to small as well as large craft, as no boat can catch upon the starlings there, being wide enough for most vessels to go through sideways.

I apprehend, the small locks most used by small boats should be planked or lined, which will be of service to the starlings, and, at the same time, prevent boats from catching upon the irregularities of the piling, in which, I apprehend, consists the greatest danger in passing London Bridge on tide of ebb, with the water below the starlings.

I am informed there are several stumps of piles in several of the locks; but while I was making my observation, there was always too much water to see them; it would be right to saw or cut them off with a large chisel made for the purpose, but not to draw them or drive them down.

Respecting the bank opposite Fishmongers' Hall; the methods foregoing tend to procure a true set of the tide through the great arch; but I know of no bank, either

above or below bridge, that is of material consequence to the water-works; the current sets over from the water-works towards the great arch, not because it is impeded by a shoal, but because it finds a readier passage that way.

REFERENCE TO THE PLANS ANNEXED.

Plate I.

Fig. 1.—A, the shaded space shews the pier, starling, and bed of the river, which, before the alteration, were solid, but which, at the beginning of February 1763, were converted into water-way.

N.B. The light shaded spaces shew the dimensions of the water-way in each lock, taken at such part where the bed of the lock is highest. The figures above the spaces are the widths of the respective locks (the piers and starlings between them being omitted), the figures beneath are the depths taken from the surfaces of the starlings at the place where the depths are least.

E E are two locks, the first and second from the Surrey shore, which, before the alteration, were open, but which were closed up by dams of piles, in the beginning of February 1763.

Fig. 2.—The light shaded spaces shew the intended dimensions of the water-ways of the respective locks, as they will be after the proposed alteration, the widths, except the great lock, are the same as fig. 1, and the depths are specified beneath.

C C C C C C—Solids, added in order to raise the depths of the respective locks.

D D—Two locks to be closed up with dams of piles to the height of the starlings.

E E—Two locks already closed, which are to remain so.

f f—Solids, to be added to strengthen the starlings within the great arch, three feet thick on each side.

N.B. Both these sections suppose the water-ways laid together, both above and below the starlings, and all the solids removed, except such as are the subject of the alterations.

The measures differ something from those before taken, by reason of their being taken at different places.

Fig. 3.—R shews the disposition of the fender piles, extending from the great lock to St. Mary's, to prevent the craft getting foul of the two intermediate locks.

D D—Locks which are to be closed up, as before stated in fig. 2.

E E—The same as fig. 2, and C, the six locks to be raised, as in fig. 2.

The names of the different locks in this figure, and the numbers, which are the same in fig. 1 and 2, will point out the names in the latter figures.

Fig. 4.—Plan, and fig. 5, section of the proposed alterations under the great arch.

H—A body of Kentish rubble for lining the bottom of the river under the great arch, to resist the action of the water, and for raising the bed of the lock for the service of the water-works, leaving five feet depth of water over the crown of the dam at low water, for the service of the craft.

I—Blocks of Portland stone, eight feet long up and down stream, and two feet six inches thick, for capping the top of the rubble.

K K K—Ground pier of larger rubble stones than the rest, for supporting the smaller until a complete bed is formed.

Fig. 5.—L L—dotted lines, shewing in what manner the starling of the great arch may be enlarged three feet on each side.

APPENDIX.

Investigation of the Answer to Question 1st, viz.

1st. In what degree, at a monthly average, is the natural power of the water, and effect thereof, upon the wheels of London Bridge water-works diminished by the removal of the pier, and opening of the great arch?

An exact solution of this question is, perhaps, impossible, on account of the very great variety of circumstances that affect it; yet, from the great number of observations that I have made upon the bridge and water-works, relative thereto, by attending to the most material and leading circumstances, and by repeating such as are of small account, or whose effects are likely to balance each other; I flatter myself that what is here offered, will be found sufficiently near the truth to fulfil the purposes for which the question was proposed. And here I must premise this principle, that where water moves through confined passages, which occasion a sensible pen or difference of elevation of their surfaces, above and below the passage, the water moves through the same as one column, that is, nearly the same at bottom as at top, abstracted from friction; and, therefore, that an increase of depth is of equal consequence with an increase of width. This appears from reason to be the case, since every part of the effluent column is put in motion by a column of the same height, viz. one whose height is equal to the difference of the two surfaces; this is also confirmed by experience, and in the present case is remarkable, since it was the action of the effluent column upon the bottom of the river, that has removed such a large quantity of matter from under the great arch.

On this account I have taken the section of all the water-ways below the starlings afresh, and as I did not confine myself to any particular part of the locks, but where I found the shallowest part, there I took the width between the starlings, this occasions some difference between these and former measures.

Plate I. Fig. 1. Is a section of the water-way at London Bridge, in which the dark shaded place A, represents the solid of the pier, starling, and ground upon which they stood, before the alteration; which solid being converted into an opening, and the first and second arches from the south shore being closed up to starling's height, shews the section of the water-way the beginning of February 1763, from whence it appears, that when the surface of the water is at the heights hereunder expressed, the sum of all the water-ways, taking width and height together, was

	3½ Feet above the Starlings.	At Starling's Height.	3½ Feet below the Starlings.
Before the alteration	4365	2524	1656
Beginning of February 1763	5245	3231	2244

Within these limits the principal part of the business of the water-works is on an average performed. The mean proportion, therefore, of the increase of water-way, above and below the starlings, will stand thus:—

At 1 foot 9 inches above the starlings, as 3444 to 4238.
At 1 foot 9 inches below the starlings, as 2090 to 2737.

Let us now consider what alteration will be produced in the motion of the water through the openings enlarged in the proportion above specified. London Bridge may, in some measure, be considered as a sluice, through the openings whereof the

water of one part of the river is discharged into the other, moving one way or other according as each surface is respectively higher or lower. Now, if the water's passage is enlarged, the water will be discharged sooner from the higher to the lower; but not so much sooner as in proportion to the increase of opening, because that would require the same velocity to be continued, and, consequently, the same difference of elevation of surfaces to be preserved; which cannot be, unless a greater quantity poured into the pool below in the same time, could run off without swelling to a greater height, which is impossible. The difference of surfaces, therefore, being lessened, the velocity of the water will be diminished, which depends thereupon, and the time proportionably lengthened. On the other hand, since the quantity of water, sooner or later, must pass through every section of the same river, if any section is enlarged, the velocity will be diminished, and diminished in the same proportion as the section is increased, where the water has a free passage and goes off as it comes, without being pent up; but when, being pent up, a part of the obstacle is removed, the velocity of the issuing water is diminished on the account before mentioned, but not so much diminished as the section is increased, because, were that the case, the head of accumulated water would be as long in running off through a larger opening as through a smaller, which is contrary to our first position, and to matter of fact. The enlargement of the water-way, therefore, acts two ways; that is, partly by diminishing the time in which a given head is run off, and partly by diminishing the velocity of the water so issuing; and since each of these principles has an equal claim, they will be separately and inversely, as the lesser water-way to a mean proportional between that and the greater.

Now, if the effects of these two principles upon the water-works followed the same proportions, they might be both considered together as one; and the diminution of effect of the water-works would be simply as the increase of water-way; but this they do not, for the diminution of effect on account of time will be as the diminution of the time simply; but the diminution of effect on account of velocity, will be as the square of the water's velocity; for the wheels will not only diminish their velocity in the same proportion as the velocity of the impelling fluid diminishes, but their velocity will be further diminished in proportion as the impulse is weaker thereupon, and the impulse being weaker in proportion as the diminution of velocity, the velocity of the wheels acting against the same load will be diminished in duplicate proportion, that is, as the squares of the velocity of the water, as I have had formerly an opportunity of proving by many experiments.

The effect, therefore, of the enlargement of water-way upon the water-works, being compounded partly of a simple, partly of a duplicate proportion of the enlargement of the water-way, will be in a proportion between the two, that is, the proportion which is called sesquialtera.

Now, taking the sesquialtera proportion of the above-mentioned enlargements, viz.

	Direct proportion.	Sesquialtera.	
Above the starlings ..	3444 : 4238	3444 : 4702 i. e.	1 : 1·365
Below the starlings ..	2090 : 2737	2090 : 3120	1 : 1·500

the diminution of the effect of the wheels will, therefore, be,

At a medium above the starlings, as 1·365 : 1
At a ditto below ditto..... 1·500 : 1

But the general proportion upon the whole will be compounded of the above proportions, and of the times of the continuance under the above proportions respectively.

At a neap tide, February 8th, the wheels, at a medium, worked five hours; and at a spring tide, February 15th, $6\frac{1}{2}$ hours. The respective times above and below starlings were as follow:

	Above the starlings.	Below the starlings.
Neap tides	$1\frac{3}{4}$ hours	$3\frac{1}{4}$ hours
Spring tides	3 ditto	$3\frac{1}{2}$ ditto
	Sum $4\frac{3}{4}$	$6\frac{3}{4}$

Now, as it is the proportion, and not the absolute quantity of time, above and below the starlings, that comes under the present consideration, it is of no material consequence, though the length of time during which the water wheels continue at work each tide should differ sometimes from those observed, provided the proportion of the time above the starlings to that below is nearly the same, which we may reasonably presume: Multiplying, therefore, the number 1·365, expressing the proportional difference of the effect of the wheels while the water is above the starlings by the sum of the times $4\frac{3}{4}$, we shall have 6·48375; and, in like manner, multiplying 1·5, the number expressing the proportional difference of effect below the starlings, by its correspondent sum, $6\frac{3}{4}$, we shall have 10.125.

Now $4\frac{3}{4}$	6·48375
$6\frac{3}{4}$	10·125
Sum of the times $11\frac{1}{2}$,	the sum of the products 16·60875;

and dividing the sum of the products by the sum of the times, we shall have 1·444, which will express the mean proportion of effect above and below the starlings, the proportion of time considered and included; which proportion of 1·444 to 1, or 1444 to 1000, would be the proportion of the power of the water before and since the alteration, did not some other cause intervene, which, though of less consideration, may not inconveniently be brought to account.

The water-way of the great arch being much more open and free than the rest, it is reasonable to suppose that the velocity of the water is less impeded by friction than in the others, which will increase the proportional discharge by the great arch, and, in consequence, increase the above proportion. I found, by experiment, that when the water was at its medium workable height below the starlings, its velocity was $\frac{1}{5}$ quicker through the great arch, than through the rest at a medium; but as the difference when the water is above the starling will be considerably less than as above specified, and yet it will be something, I therefore take $\frac{2}{3}$ of the above quantity, that is, $\frac{2}{15}$ for a medium of the whole. Now, $\frac{2}{15}$ of 1444 is 193, which, being added, make 1637 : 1000, for the proportion once corrected.

2dly. On account of the increase of water-way at London Bridge, I find that the tides rise, at a medium, four inches higher above bridge than they did before; and that at a medium the rise is from low water above bridge, about eleven feet; so that the body of water is increased in perpendicular height, and at least in quantity, by $\frac{1}{33}$ part of the whole. Now, this additional quantity will act upon the wheels in the same manner as the main body, that is, partly by increasing the velocity, and partly by lengthening the time; its effects will, therefore, be in a sesquialterate proportion of the quantity, that is, near $\frac{1}{23}$ part of the whole, and of course will lessen the number 1637 before stated; therefore, $\frac{1}{23}$ part of 1637, which is 71, being taken away therefrom, the remainder will be 1566; so that 1566 to 1000, will express the proportion in which the natural power and effect of the water upon the water-wheels is diminished by opening the great arch, exclusive of such causes and irregularities as cannot be brought into the account.

Ever since the year 1756, a daily register has been kept at the water-works, containing the time of high and low water, the height to which the tides rose above bridge, with the number of strokes of flood and ebb that was made by each pump of the westernmost or first wheel in the fourth arch. To this book having, by permission of the company, had free access, I have endeavoured to extract therefrom such materials as might ascertain their average performance, before and since the alteration of the great arch: this I did by extracting three adjoining of the best spring, and three adjoining of the worst neap, tides, during the course of a month, at each quarter of the year; the months were March, June, September, and December, which take in the equinoctial and solstitial tides, and the summer waters will be balanced against the winter; so that the average tide for each year was collected from the medium of forty-eight tides, critically chosen at such seasons as were most favourable, and most unfavourable for the performance of the engines. An abstract of which is as follows:

		Number of strokes.
Average tides for the latter half of the year	1756	2803
for the year	1757	2888
do.	1758	3029
do.	1759	3215
do.	1760	3099
do.	1761	3142
for the first half of the year	1762	2998
	Sum....	21174
	Mean ..	3025
Average tide for July	1762	2846
August	do.	2448
September	do.	2193
October	do.	2121
November	do.	2090
December	do.	1689
February	1763	2248

From the above, it appears that for six years preceding the alteration, the average performance of this engine was 3025 strokes per tide.

That from the time of beginning to take away the starling, the performance gradually lessened, till December, when it fell remarkably short, and as remarkably increased in the month of February; which irregularities were undoubtedly owing to the remarkable drought in the month of December, preceding the frost, and at a season when the tides at sea naturally run short; and the other to the remarkable tides and floods that succeeded the frost; so that, balancing those two months against each other, the average will be 1968: but if we take the four months of October, November, December, and February, since the alteration, the average will be 2037. So that, comparing the average performance of those engines, before and since the alteration,

they will be as	3025 to 1968, that is, as	2000 to 1300.
	3025 to 2037	2000 to 1346.
but, by calculation, as	1566 to 1000	2000 to 1277.

Hence it appears that the deficiency, as obtained by the company's register being at most 700 in 2000, is not so great as results from calculation, which amounts to 723, whereas, from considering the great proportional increase of friction in the works, when acted upon by a smaller power instead of a larger, one would have expected the difference to have been on the other side.

But this I apprehend to be balanced, and perhaps more than balanced, by the following circumstance:

It has been already proved, that the wheels work slower than before in a duplicate proportion of the difference of the water's velocity; suppose this, for argument's sake, to be $\frac{1}{4}$; now, if the wheels work at a medium $\frac{1}{4}$ slower than before, the water will move $\frac{1}{4}$ slower through the pipes, which amounts (respecting the engine) to the same thing as if the area of the pipes were made $\frac{1}{4}$ larger: in consequence whereof, the water moving to its place of destination with greater facility, will not require so tall a column to impel it, so that the water will not rise to so great a height in the stand pipes, and, in consequence, the engine acting against a less column of water will tend to revolve faster, and in so doing will, I apprehend, in the present case, produce an equivalent to the greater proportion of friction.

1763. J. SMEATON.

ESTIMATE

For the Works specified in answer to Question the 3d.

	£.	s.	d.
To 3000 ton of rubble stone for raising the bed of the river under the great arch, and securing the same, at 10 shillings per ton	1500	0	0
To 320 feet running of additional wharfing to the starling of the great lock, at 4*l.*	1280	0	0
To 1040 cube feet of Portland blocks, for capping the crown of the dam of rubble under the great arch, laid in place, at 3*s.* 6*d.*	182	0	0
To 240 feet superficial of plank piling, for stopping up Chappel and Long Entry Locks, at 5*s.*	60	0	0
To 2000 ton of rubble, for raising the beds of the five other locks, at 10*s.*	1000	0	0
To 4200 cube feet of fir timber, to make the fender piles before Long Entry and Chappel locks, including brace piles and braces, every thing fixed in place, iron work included, at 4*s.* per foot	840	0	0
	4862	0	0
To contingencies upon the above accounts, at 10 per cent	486	0	0
Total	£.5348	0	0

N.B. It will take 2000 tons of rubble to line the bed of the river under the great arch, for the security thereof. The second article is chiefly calculated for the same purpose; and the last article, being wholly for the service of the navigation, which may be applied or not after the other works are performed, as the use or necessity of the thing shall direct. These articles being deducted from the above estimate, there will remain £1742 to be expended on account of the water-works; which, with its proportion of contingence, comes to £1916. The necessary repair of the starlings, on account of the damage done by the ice, is not included in the above estimate.

THE REPORT

Of JOHN SMEATON, Engineer, concerning the State of the great Arch of London Bridge.

HAVING carefully viewed the piers and starlings, and taken soundings of the depth of water, both underneath and for some space both above and below the great arch of London Bridge, before, at, and after low water, on Friday, the 25th July, 1766, I

have the pleasure to assure the committee, it does not appear to me, that either of the piers, or the arch dependent thereon, has given way in the smallest degree; nor does there appear to be any crack or settlement therein, by failure of the foundation or otherwise, that I observed; and though a part of the outworks of the south pier has suffered some derangement by the continued action of a very rapid and powerful current, yet, by the seasonable application of 200 tons of rubble stones, it appears to be secured for the present, so that I don't find the structure in immediate danger. Having said thus much for the satisfaction of those who may have supposed otherwise, I will now proceed to report the result of my own observations, as to the causes of the present failure, and what appears necessary for further security: but first I must premise, that

When I was called upon, in the beginning of the year 1763, I found the depth of water under the great arch, at low still water, to be twenty-two feet, the current making hourly depredations upon the starlings, the south-west shoulder of the north pier undermined six feet, and the original piles, upon which the old works had been built, laid bare to the action of the water, and several of them loosened. In this perilous state, when a settlement of that pier must necessarily have taken place in a few days, I proposed the only remedy I knew of, that was likely to be attended with success in circumstances so pressing, viz. that of securing the bed of the river with a body of rubble stone, upon which the said angle was under-pinned, and so far secured, that it has never yet shewn any defect. It was also thought proper to raise this body of rubble so high as to pen up the water for restoring London Bridge water-works to the same power as before the alteration, and to defend the starlings next the great opening, by an *additional* outwork of three feet broad, on each side, surrounding the former casing: which matters were fully set forth in my former report, dated 18th March, 1763.

On sounding at low still water, on Friday 25th, I found no where more than eleven feet water, and in general not above eight feet, immediately under the great arch, but above and below, in a line, and at the points of the starling, I found twenty-four and twenty-five feet water below, and from twenty-two to twenty-six feet above bridge. I also found in going downward, in the direction of the stream, at the distance of about thirty-five or forty feet below the points of the starlings, the water to deepen to thirty-three feet: and at seventy or eighty feet, which was the deepest place, thirty-eight feet. On the upstream side of the bridge, about fifty feet above the point of the starlings, I found twenty-eight feet water.

From the above soundings it appears evident, that from the continual wear of the very powerful and rapid current which sets through this arch, that the bed of the river, above and below the points of the starlings, has been worn away to a much more considerable depth than it was in the year 1763; in consequence of which the bed of the river, from the points of the starlings upward and downward, forming a slope too great for the rubble to lie upon, when impelled by so strong a current, the skirts of the rubble will naturally slide into the cavities: this, in consequence, has impoverished the body of rubble immediately under the arch, which it did on the south side so as to loosen the piles for about twenty feet in length, of the additional casing that had been driven into, and had their fixing in the body of rubble; but which, by a timely supply of same material, are now made firm, and this part of the body of the bed of rubble is as high as any of the rest, so that no immediate danger is hence to be expected.

The reasons why the failure of the outward casing happened on the south side, I apprehend to be the following:

1st. That as it was the north pier that complained in the year 1763, the principal attention would naturally be directed to that side, and, in consequence, the best and largest rubble be deposited there.

2d. From the natural set of the current of the river, which for the space of about 100 yards above the bridge sets obliquely over from the north side to the south, and will, in consequence, strike against the north face of the south starling of the great arch, this cross set of the tide is rendered still more oblique by the particular situation of the arches that are stopped up. When my report of 1763 was made, I found the two locks next the Surrey shore stopped up, and advised the two small locks next the great arch, on the north side, called Long Entry and Chappel locks, to be stopped up likewise: this, with the proposed alterations under the great arch, and the raising the beds with rubble to a certain height, of five other locks, which I found unnecessarily deep, (all which were specified in a draught attending my report), appeared, in my opinion, sufficient to restore the water-works to their former power. Upon my view, on Friday the 25th, I observed that the two locks next the Surrey side were open, and was informed that none of the beds of the five locks had been raised, but that, in lieu thereof, the fifth lock from the north shore had been and remains stopped up. Now, if all the locks on one side of the great arch were stopped up, the current would be obliged to make its way towards the open side; the stopping up, therefore, of the fifth lock, on the north side, and the opening of two upon the south side, must necessarily conduce to carry the current more obliquely towards the south side than it would naturally do; whereas the stopping up of the two arches proposed by me on the north side, would have been no more than a counterbalance to those I found stopped on the south side. I did, indeed, suggest in my former report, that in case it should be thought eligible for navigation, two pair of pointed gates, so as to form a navigable pen lock, should be placed in the fifth arch from the north side: in which case, the raising of the bed of St. Mary's lock, and the stopping up of Chappel lock, or Long Entry, might be dispensed with; but this I did not recommend as preferable to my first scheme, unless more eligible on account of navigation. Upon the whole, it is to be wished, for the sake of security to the bridge, as well as navigation, that some equivalent could be formed to the water-works, so that all the arches might be unstopped; the great arch remaining as it is.

I now come to advise what is further necessary, in my opinion, to be done for the security of the bridge, which principally consists in guarding against the derangements that probably will arise from the deepening and wearing away of the ground above and below bridge; and for this purpose I would advise, that, with all possible dispatch, a further quantity of Kentish rubble be deposited between and at the four points of the starlings of the great arch, so as to lessen the too great depth and slope of the bed of the river and of the rubble, to the end that the rubble so deposited may not work down into the pools; it would be advisable so far to lessen the depths thereof, by dropping in rubble, as to make a firm footing for the rubble that lies immediately more contiguous to the piers and starlings; further than this would be rather detrimental than useful.

After all, it will be necessary that the condition of the rubble bed should be frequently examined, and to have always in readiness a quantity of rubble to supply such deficiencies as, from time to time, may happen; for, though this method will, like the starlings and the rest of the ground-works of this bridge, need occasional temporary supplies, yet, being duly attended to, there is sufficient reason to suppose that it will prove a lasting support; and, if imperfect, yet deserves the greatest

attention, because I do not know any practical method by which the great arch of this bridge, so founded and so circumstanced, can be maintained and supported without incurring much greater expenses with less certainty; and when, by the disposition of rubble, the cavities above and below are hindered from pooling, and the foot of the rubble bed, within the starlings, supported thereby, and the whole by time consolidated, it may be expected that the repairs of this part will be very inconsiderable.

London, 28th July, 1766. J. SMEATON.

To the Right Honourable the Lord Mayor, Aldermen, and Commons, in Common Council assembled.

MY LORD AND GENTLEMEN,

IN answer to the order of common council, of the 13th day of March, in which I am desired to *take into consideration the state of London Bridge; of the navigation under the same, and of the London Bridge water-works; and also the proposed alterations suggested in the committee's report, and to give my opinion upon the same;* I must beg leave to refer the honourable court to my former report, of the 5th of February, wherein is contained the most material part of what I can observe upon the subject.

I, therefore, consider what I now further offer as supplemental thereto.

Respecting the state of London Bridge, I look upon its greatest weakness to be in its foundations, being chiefly built upon piles, sawn off above low-water mark; and this construction considered, I am of opinion, that the less the fall and velocity of the water is, in passing the bridge, the less subject to those piles, together with the starlings and other works for defending the piers, are to get out of order, and into disrepair, and, consequently, the *less fall*, the greater security to the bridge.

The alterations suggested to the committee (as appear in my paper above referred to), directly tend to diminish the fall and velocity of the water; and, therefore, so far as that difference goes, it is in favour of the foundation of London Bridge.

I apprehend this honourable court is, by the act of parliament for the alterations of the bridge, obliged to keep up a head of water for working the engines as effectually as they were worked before the alterations; and, if so, I am clearly of opinion, that the fall and velocity must be maintained greater than they will be, in case the alterations *suggested in the committee's* report, are carried into execution; and, therefore, that consistently with the maintenance of power to the London Bridge water-works, the fall will be reduced, by the proposed alterations, as much as it can be, and for this reduction that the grant of the further arches may, in some measure, be considered as a compensation for the loss of power that they would otherwise sustain by the other parts of the proposal.

With respect to the navigation immediately under or through the bridge, as nothing can be more clear than that whatever tends to diminish the fall and velocity of the water there, must be of benefit to the navigation, the only question that can remain on this point is, whether, by diverting the navigation from the first and second arches on the Surrey side, it will lose any thing material?

The particular uses of these arches to navigation is matter of experience and practice which I have not had; but, in my own opinion, I apprehended them to be in this respect of very little benefit, and am the more confirmed in this opinion, by

having found them both stopped up (and the only ones that then were so), for the assistance of the water-works, when I was called upon in this affair, in the year 1763, and the reason then given was, that those two arches were looked upon as the least useful of any in the bridge, for the purpose of navigation; the difference, therefore, in point of navigation, immediately under the bridge, seems, upon the whole, in favour of the alteration proposed; but, if we consider the navigation of the Thames above bridge, I am of opinion, that were the fall at the bridge considerably reduced, *by any means whatever*, the navigation of that part of the river would be *materially* affected.

It is difficult at this time to determine, whether the bed of the river Thames was as high above bridge before London Bridge was first erected, as now it is; and whether the stoppage of the water at the bridge, acting as a dam, was an *expedient* to retain more water in the river at low-water over those shoals for the sake of navigation; or whether this stoppage arising from the construction has, in its *effects*, occasioned the fullage of the river gradually to gather, and the bed to rise nearly in the same proportion as the water's surface at low-water is kept higher? However this might be, it is certain the bed of the river above bridge, is now, in *proportion, higher* than it is below bridge.

If London Bridge were, therefore, to be taken away, the river would become so shallow above bridge, at low-water, that the navigation would be greatly impeded for hours each tide.

If this difference of bed was *original*, we must expect it to remain; but if an *effect*, the cause being taken away, the river would gradually restore itself; but as this might probably take up seven or eight hundred years (the time it has probably been gathering), the work of restitution would go on far too slowly to answer the demands of the present generation.

That a stoppage at London Bridge, in the present state of the bed of the river above bridge, is necessary to the present navigation thereof; and that it cannot greatly be reduced, without detriment, is more than speculation. The ill effects were experienced during the time that the bottom of the river was gulled underneath the great arch to the depth of above 20 feet at low-water, when, by means of so great a water-way, the tide-water was discharged so much more speedily, as not only to prove greatly detrimental to the power of London Bridge water-works, but also to the navigation of the river above bridge.

If, therefore, the keeping up of a certain head of water be necessary to the navigation above bridge, and to enable this honourable court to acquit themselves of what is enacted respecting the water-works; if the water-works will, by agreement (in consequence of availing themselves of the additional arches), be contented with *such a head* of water as will subsist after the dam proposed to be removed, and the other alteration suggested made; then will this honourable court avail itself of all the reduction that the case, in all its circumstances, will admit of; and as it appears, that some head of water must be kept up and maintained, not only for the water-works, but for the navigation, then the more *useful purposes* this head of water is applied to, the more beneficial it will be to the community.

The petitioners set forth, *that wheels under the four arches in their possession, would not act with the same velocity, at any time, as they did before the alteration of the bridge, when two arches were laid into one:* if this allegation is true, then it will follow that the head of water has never been so great, since the alteration, as before. And, on this occasion, I must, in justice, declare, that the several matters contained in my report of 1763, on purpose to restore the head of water, have never been fully put in execution; and that, except what has been done under the great arch, no part of the directions therein contained has been pursued, except the stopping up of

Long Entry and Chappel locks; the doing whereof has since been complained of, as making an eddy; and that, in lieu of other alterations by me suggested, the fifth arch was stopped up as it now remains, and with which, I suppose, the company were contented; but which, in my opinion, was not equivalent to the head of water that would have been gained, had the several alterations proposed by me taken place. Hence, it most evidently appears, that if the honourable court should not confirm the proposed agreement between the committee and the company, instead of reducing the head of water still further than it now is, by the further proposed alterations, the court will be obliged to support a greater head of water than has ever subsisted since the removal of the old pier under the great arch; which, as has already been said, is what, by all means, ought to be avoided, both on account of the bridge and of the navigation.

As the Long Entry and Chappel locks were stopped up in consequence of the directions in my report of 1763, it may not be an unseasonable digression to say a word or two on that subject. It appeared to me, from computation, that in order to restore the head-water, as prescribed by the act, it was necessary to stop up some of the locks, and raise the bed of others. In order to specify which locks should be stopped up, I inquired which of them were least useful to navigation; and, among others, Long Entry and Chappel Locks were mentioned, as being both too narrow and too shallow. In order to destroy, as much as possible, the effect that might be produced by stopping up of locks on one side of the great arch, more than of the other, I proposed to have stopped one of the locks next to the great arch, on the Surrey side, which, together with the two locks that I found stopped (and proposed to have remain so), next the Surrey shore, would have made three stopped arches on the Surrey side, and two on the London side; but, instead of this, the dams on the Surrey side were removed, and the fifth arch from the London side stopped up, which made three stopped locks on the north side, and none on the other, by which means the balance of current on each side of the great arch, not being preserved, the current of the great arch must, necessarily, tend to that side where it meets the least resistance; that is, towards the two adjacent stopped arches, and form a greater eddy there than it would have done, had its tendency been equal both ways.

In my last report, I have declared it as my opinion, "that three locks being stopped up on the north side of the great arch, and none on the south, is the greatest artificial cause of the eddy complained of, and that the changes proposed are the most likely and easy means to remedy the same."

It must not, however, be expected, that the eddy of the great arch will be wholly removed by taking away the dams from the locks above mentioned; for so far as it depends upon a superior strength or column of water, penetrating into the body of more still water below, it must be expected always to remain.

Upon the whole matter, I am clearly of opinion, that considering the advantages to the security of the bridge, arising from an easement of the fall below, and the being clear of the pipes above, to the navigation through the bridge, and also to the navigation of the Thames above bridge, this honourable court cannot do better than confirm the proposed agreement, which the committee have formed with the proprietors of the water-works; it being, I suppose, clearly understood, that the said proprietors give up all claim to further alteration of the bridge, from its present state, on account of the head of water directed by the Act of Parliament to be maintained.

I am, my lord, and gentlemen,

Your most obedient, and most humble servant,

London, June 23, 1767. J. SMEATON.

INSTRUCTIONS

For Mr. NICHOLLS to proceed with the Water-wheel and Spur-wheels for the great Engine, to be erected under the fifth Arch of London Bridge.

	Feet.	Inches.
1st. The diameter of the water-wheel, to the extremity of the floats	32	0
2d. The diameter of ditto in the rings, out and out	27	0
3d. The width of the wheel, or length of the floats, to be as great as a sufficient clearance of the lock will allow; I suppose	15	6
4th. The number of the floats to be 24		
5th. The width of each to be	4	6
6th. The diameter of the spur-wheels to be, in the pitch circle	14	0
7th. The number of cogs 80		
8th. The number of ditto in the lanterns 23		
9th. The water-wheel gudgeons to be in diameter	0	7
10th. Length of the cylinder part	0	7

REMARKS.

I suppose the water-wheel to stand as near the arch as possible, to leave a sufficient clearance, and to go as near the bottom as possible to be safe.

2d. I propose the tails of the starts to reach through the rings, so as to support the inside floats, and to make up the whole breadth 4 feet 6 inches; the rings to be clasped by the boards, half-way from one side, and half-way from the other.

3d. I suppose that four rings will be sufficient, at 4 feet distance, middle and middle; more rings than necessary, on account of strength, being prejudicial.

4th. I suppose the gudgeons to be fixed on crosses, 7 inches in breadth, on the face, and $7\frac{5}{8}$ breadth on the inside, and to be $3\frac{1}{2}$ inches thick. One hoop at each end will be sufficient, and should be 5 inches broad, and at least $\frac{1}{4}$ (but better of 1 inch) thick; it should have eight holes for strong short spikes or dowells, two in each quarter, and about $1\frac{1}{4}$ or 2 inches from the inside; the hoops should be adapted to the crosses, but to bring all home tight, a groove in each end should be left for iron wedges, as described in the elevation, Plate 35. As the intersection of the cross will form a base larger than the gudgeon, this is to be filled up by a fillet of about $\frac{1}{2}$ an inch projection, according to the length of the axis, which will not only strengthen the joining of the gudgeon to the cross, but make a regular shoulder, which will keep the end of the axis clear of the head stock. The different breadths between the faces and back of the arms of the cross forming a dovetail, will, when wedged in, be alone sufficient to keep them fast, but, not depending altogether on the wood, four screws, of about 1 inch diameter, are put in about 4 inches within the ends of the cross, as described in the elevation, Plate 35, which fasten with four nuts, let sideways into the distance of about 8 inches behind the inside of the hoops, which done, the holes are plugged up again in the manner of bed screws. The heads may be cylinders of about 2 inches' diameter, and 1 inch in length, to be sunk with a square shoulder, flush with the arms. N.B. The hoops must be as large as the wood will allow.

5th. I suppose the construction of the arms, rings, starts, and floats, to be according to the method of fixing which has been found, by experience, to answer best; as also the spur-wheels are proposed much larger than what has been used before; that in case compass arms cannot easily be procured, in order more equally to support the circumference, the square formed by the clasp-arms may be 1 foot on a side, if necessary, larger than the axis, which, being filled with blocks, and wedged, may be fixed as tight as if the axis were of that size.

NEWCASTLE, July 17, 1767. J. SMEATON.

TO THE COMMITTEE OF LONDON BRIDGE WATER-WORKS.

GENTLEMEN,

Having carefully examined and considered the construction of your fire-engine, I am of opinion as follows: That as in the present situation of the pipe for supplying the well, the engine cannot have a proper quantity of water at low-water, I entirely approve the proposition of laying a horizontal suction pipe, in order that the engine may take the water immediately out of the Thames.

This will, however, lay some additional burden upon the engine; but as at present it works by a secondary power, that is, the power of the atmosphere lifts a weight, which weight, in descending, raises the column of water, the addition of burden would be more than compensated were the engine made to raise its column immediately by the power of the atmosphere.

To produce this effect, it will be necessary to change the working barrel, with the valves and machinery dependent thereon; and at the same time that the working piece is changed, a new one may be introduced, whose proportion will be more advantageous.

At present, the whole of the water raised by the fire-engine is raised to the top of the tower, 120 feet high, as I am informed, though it most commonly happens that one-half, two-thirds, or three-fourths of that height, would be sufficient. I would, therefore, propose it as a very material improvement, not only to save fuel, but to raise more water, to unite the main from the fire-engine with those from the water-engines, by which means the fire-engines will, like the water-engines, never be burdened with a greater column than is sufficient for the service then on: to this I am sensible there is an objection, viz. that the column to be lifted by the fire-engine being then variable, the fire-engine will not work with the requisite degree of steadiness, which would certainly be the case in the ordinary way of applying the injection, but as I have found out and experienced a method of applying the injection, whereby the engine-keeper is enabled, extempore, while the engine is working, to vary the quantity proportionable to the column to be lifted; hereby the ill effects arising from a variation of the column will be altogether prevented, and a proportionable saving will be made in the fuel.

As the engine at present, when lifting the whole column to the top of the tower, would bear a greater load, and would consequently be considerably under loaded when the column was lowered as above proposed, instead of a twelve-inch, as now, I would propose to put in a thirteen-inch working barrel, by which means the engine will every stroke raise one-fifth more water; and, by virtue of the changes above mentioned, I expect the coals will be reduced from three bushels per hour, as at present, to two at an average.

Some other smaller alterations may also be made with benefit: and the whole machine wants a repair, particularly the arch heads and chains, and the beam will want to be strengthened.

The boiler is too small for the cylinder, and not of the very best proportion; but as I understand it is in good condition, and may serve some years, I do not at present recommend any alteration in that part.

LONDON, March 8, 1771. J. SMEATON.

P.S. I do not mean that the engine will lift the water to the top of the tower

with two bushels of coals an hour; but I expect it will (besides the additional load of suction) work a thirteen-inch working barrel in lieu of a twelve, and without any additional quantity of coals, in consequence of altering its mode of lifting.

11*th March.* J. S.

THE FORTH AND CLYDE NAVIGATION.

To the Honourable the Trustees for Improving Fisheries and Manufactures in Scotland.

The Report of JOHN SMEATON, *Engineer and F. R. S. concerning the Practicability and Expense of Joining the Rivers Forth and Clyde, by a Navigable Canal, and thereby to Join the East Sea and the West.*

The great utility of a navigable communication between the east sea and the west, has given occasion to several projects for this purpose, in different parts of the kingdon of Great Britain. The principal of which are the Thames and Severn, the Trent and Severn, the Trent and Weaver, the Calder and Mersey, and the Forth and Clyde. But from what I have seen and heard of these matters, I am well convinced, that by far and most easy to be accomplished, not only in point of distance, but in point of perpendicular height, is the last, and it is somewhat remarkable, that notwithstanding the country at this place lies in general as high, if not higher, than any of the rest; yet, that through this high ground, there happen to be two different passages, both lower than any of the others, and so much appearance of equality in point of practicability, that upon ocular surveys, it has remained a doubt which of the two ought to be preferred.

One of these passages is from the river Carron, by way of the water of Bonnie, through the bog of Dolater into the Kelvin, and from thence into the Clyde by way of the Yocker-Burn. See the plan, Plate 37, fig. 2.

The other is by following the river Forth some miles above Stirling, and then crossing over through the bog of Bollat into the water of Enrick, down to Loch Lomond, and from thence by the river Leven into the Clyde, at Dumbarton (see the map, Plate 37, fig. 1.), and as I have, by order of the honourable the trustees for improving fisheries and manufactures in Scotland, been at some pains in taking proper observations in order to determine the preference of the two passages, I shall first endeavour to settle this question, and then proceed more minutely to explain the several leading points that occur for laying out the design for the preferable tract.

GENERAL DESCRIPTION OF THE CARRON PASSAGE.

See the Plan, fig. 2. *and the black line, fig.* 1.

From the Forth to about three miles up the river Carron, to a place called Carron Shore, there is at present a good navigation for sea-vessels, drawing from nine to

ten feet water, at spring tides, and from seven to eight at neap tides, which, from the cuts proposed to be made across the Loops, as I am informed, is likely to be improved; and so far I consider the present sea-navigation to extend.

From Carron Shore to Top-hill, a little below Camelton Bridge, the ground is gently rising, and adapted as well as possible for a canal. From thence to the point above Camelton, between Newhall and Glenfour, the ground rises near sixty feet in half a mile, and is more uneven, but yet attended with no considerable difficulty; from thence the canal may be managed upon the decline of the high ground so as to run upon a dead level to Castle Cary Bridge, being about four English miles; this tract of ground is intersected with haughs and burns, which occur very frequently, and will, therefore, require a considerable expense in making banks, aqueducts, and other extra works, yet nothing occurs but what may be conquered at a reasonable charge. The principal single work will be an aqueduct bridge in crossing Bonnie mill Burn, near Bonnie Bridge, over which the canal must be carried upon arches. Another, but less work, of the same kind, will be required in crossing the river Bonnie, at Castle Cary Bridge. From hence to the bog of Dolater, which begins a little above Wineford; the passage is sufficiently easy by a gentle ascent, and through the said bog, (extending almost to Craigmarline wood), there is scarcely four feet descent either way, in the compass of two miles; about the middle of which is the summit between the two seas, and is elevated above high-water neap tides, at Carron Shore, about 147 feet, being distant therefrom about nine English miles. On each side of Dolater bog the country rises high, which affords a number of springs and rills, which brings down considerable quantities of water on the least rain; but the principal, which is constant all the year, is the burn of Achinclough, which discharges itself into the bog, and which, though it now runs into the waters of Bonnie, might, with very little trouble, be turned, so as to run the other way into the Kelvin; for a drain that now passes lengthways through the bog, has, for half a mile in the middle thereof, no sensible run at all; so that the same trench is the head both of the Bonnie and Kelvin. This bog, as it is called, is properly a peat moss or morass, and is in general near half a mile broad, but contracted at each end by the high land at A and B, to about 120 yards; so that it is adapted as well as possible for the formation of reservoirs, canals, and passages for water: indeed the whole bog might easily be put under water, by a small dam between the high grounds at each of the contracted places. From the summit, or point of partition, westward, the Kelvin runs in an open valley for about thirteen miles, upon a very regular and almost insensible decline as far as Garscud Bridge, where it begins to be more rapid, and runs through a very deep channel, quite confined by rocks and precipices, in some places almost perpendicular, and down to Partick, where it falls into Clyde. Of this district, all that can be said, is, that it is not impossible to be made navigable, but it would cost a great sum to make a bad navigation; for this reason, those who have turned their thoughts towards this project, have sought out for a new passage into Clyde; and Nature has kindly furnished two that are practicable, one by the valley of the Allander, leaving Douglastoun, Kilmardoney, and new Kirkpatrick, all on the right, and cutting through a rising ground between the two last places at C, we are conducted into a valley leading down to Grascuddon. The other passage leads out of the Kelvin's valley, just above Garscud Bridge, and going by way of Canny's Burn, traverses a rising ground at D, and falls into St. German's Loch, and from thence, by the same valley as the former, to Grascuddon. Neither of these passages is without difficulty, on account of the rising ground to be cut through, being above thirty feet perpendicular above the general level, yet both

are greatly preferable to the passage by the Kelvin, below Garscud Bridge, which, besides the incumbrances already mentioned, is filled with mills of various kinds, which occupy the ground where any cut could easily be made. At Grascuddon the ground falls considerably in a little space, and then the passage is very easy and regular down to Yocker Burn, which discharges itself into the Clyde, almost opposite Renfield, and a little above a place called Barns of Clyde. From hence downward the Clyde is navigable at all tides with any vessels that can be expected to navigate upon the intended canal, which I would propose to be such as could occasionally go from Port Glasgow or Greenock, to Leith. From the point of partition of the waters, in Dolater bog, to Barns of Clyde by the course of the canal, will measure about eighteen English miles (to which measure I all along confine myself), so that the whole length will be about twenty-seven English miles.

GENERAL DESCRIPTION OF THE PASSAGE, BY WAY OF LOCH LOMOND.

See the Map, Plate 37. *fig.* 1.

Beginning from Clyde to Dumbarton Castle, we enter into the river Leven, which, though but 6¼ miles long, measuring by the links or turnings thereof, is yet a large river, and brings down a considerable quantity of fresh water at all times of the year; for having the great lake, called Loch Lomond, for a reservoir at its head, which receives the water of several considerable rivers, it always affords a considerable currency in the dryest seasons, and is never subject to any great or sudden floods on account of the great capacity of the aforesaid lake. This river is, in a state of nature, navigable for flat-bottomed vessels from the Clyde to Loch Lomond, in winter, and wet seasons in summer; but, in dry seasons, the navigation is in a manner stopped; for though it affords a good deal of fresh water at all times, yet as it is broad, and runs in a shallow channel (except about a mile above Dumbarton), and has about twenty feet fall from Loch-Lomond to high water at neap tides, which are sensible at a place called Dalquurn Bleachfield, about a mile and a half above Dumbarton, consequently, there is twenty feet fall in less than five miles, which makes the water somewhat rapid, and, in dry seasons, leaves not above eighteen inches in depth over the shoals, which are pretty numerous; and though it might not be difficult to improve this navigation, so as better to answer its present purposes, yet it is not capable of any remedy adequate to the purpose of a general navigation, otherwise than by locks and dams, to pen up the water from one to another; for as the river checks in with the high ground, first on one side, then on the other, the valley is but ill adapted to a canal the whole length.

From the head of Leven, we traverse about seven miles of Loch Lomond, in which there is no impediment till we come near the mouth of the river Enrick, which having its source in a high country, comes down very rapidly, and brings a great quantity of sand from the mountains, which is lodged near its mouth in the lock, and there, as it were, forms a bar; over which, in the summer state of the loch, there is not above eighteen inches water, while it serves as a ford in most seasons. To attempt making a passage through this sand, by lifting the matter, would be endless; for, being situated in a bay which lies open to the west wind, the sand is brought back upon the shore by the action of the wind and waves. I have since been informed that at the south corner of this bay, near a place called Aber,

the shore is clear of sand; but being there rocky, to make a passage through the same, of sufficient depth below the surface of the loch in its lowest state, for the passage of loaded vessels, would probably be more expensive than the removal of the bar itself, which, I apprehend, might be done by running out two jetties about $\frac{3}{4}$ of a mile into the loch (for, according to my information, it is that distance from shore, in dry seasons, before we should find any navigable water,) in which case the current of the river, being confined between the jetties, would scour out the sand, and keep the passage clear.

From the mouth of Enrick, the river runs in an open valley, in a deep channel, and almost upon a dead level, as far as Cater Boat, opposite Drummond; which, in a right line, is about $3\frac{1}{2}$ miles, but by the course of the river, which is very winding, cannot be less than six. From hence to the south-west corner of Dalnair Park, the river measures $2\frac{1}{2}$ miles; the perpendicular rise is almost eleven feet. The valley so far continues open, but as the channel is very winding, and checks in with the high ground on both sides, several times, the best way of making it navigable will be by locks and dams, as the Leven.

A little above this, that is, a little above where the water of Blain falls into Enrick, the valley is quite contracted, and the river falls over a set of rocks, forming a remarkable cataract called the Pot of Gartness, marked Y, to pass which, in the channel of the river, would be very difficult, but this may be avoided by cutting across the neck of land from the south-west corner of Dalnair Park into the river above Gartness Mill, the length will be about a quarter of a mile, and the perpendicular rise about thirty-seven feet. In this passage we meet a hill, whose summit rises above forty feet higher than the level of the river, at the aforesaid cataract; but as the length of the hill is not great, it may be pierced with equal ease, and by the same means as those mentioned in crossing from the Kelvin to Grascuddon, in the other passage. This passage, by the way of Enrick, in the general map, fig. 1. is shewn by a line of strong dots.

Having regained the river Enrick, above Gartness, there seems no way but to follow the course thereof, $1\frac{3}{4}$ mile, in which space there is a rise of twenty-five feet. This passage is sufficiently rugged, and the valley confined by steep brays and rocks; nor do I see any adequate means of avoiding it, as the country hereabout is very steep and uneven; however, it may be managed by locks and dams, upon the same principle as those below. From hence, it is proposed to pass by canal to the bog of Bollat, the summit of which is distant a little more than a mile, and is elevated above the aforesaid point in the river, 129 feet, viz. from the river's surface to the top of the bray thirty-five feet, and from thence to the summit of the bog 94 feet; so that the summit of the bog of Bollat is elevated above the surface of Loch Lomond 202 feet: and above high-water neap tides in the Clyde 222 feet, the whole distance being twenty-five miles.

The bog of Bollat is about half a mile long, and about one-eighth of a mile in breadth; from the middle or summit, the ground falls away pretty quick both ways, and the valley widens: no constant running waters discharge themselves into this bog, except one small rill that comes in on the north side; there is, however, a burn, called the Auld Hurr, marked X, which falls into the decline of the valley towards the Forth, which might easily be conducted to the summit; but this, at the time I saw it, after a remarkable rainy season, was far short of supplying a navigation. There is also another burn to the west of Bollat, affording much about the same quantity, which falls into Enrick, the upper part of which might be intercepted and carried to the summit, but still there would remain a

great deficiency. I should not, however, despair, did the point of difficulty rest here, of bringing a sufficiency of water to the bog of Bollat, and making proper reservoirs there; for it appears, from the face of the country, practicable to lift the water of Enrick, four or five miles above, so as to bring any quantity required to the point of partition, or even to bring a part of the Keltie water upon a sufficient elevation round the hills to the same place.

From the point of partition in the bog of Bollat, a valley gradually forms itself to the north, into which the waters from the neighbouring hills collect themselves, and form a burn; which, passing by Achintroig, and a place called Offrings, falls into the river Forth, a little below the mouth of the Keltie. From the summit of Bollat to the river Forth is above four miles, the last mile of which being through the valley of the Forth, has but little descent, so that the greatest part of the whole descent is in the three former miles.

From the mouth of Keltie to Stirling, the river Forth runs in a remarkably winding and deep channel, and with a slow current; which is, however, interrupted at three principal places, viz. at the foot of Cardross, where there is a fall of about two feet; at the ford of Frew, where there is the like fall; and at Craigforth Mill, at N. about $1\frac{3}{4}$ mile above Stirling, where there is a fall of four feet.

The falls at Cardross and Frew are occasioned by gravel shoals formed there in the river, and brought down from the hills by the burns that fall into the Forth, near those places; but that at Craigforth mill, N. is occasioned by a natural rock, which runs across the river, the defects of which, as a dam, are made good by art, in order to produce a sufficient pen of the water, to work the mills, and to catch salmon. The spring tides come up to Craigforth mill, and the river is then navigable for lighters or barges to this place, and, according to my information, at neap tides, within half a mile below this place.

Above Craigforth mill, a navigation is at present carried on upon the Forth in small boats as high up as Gartmore, except in very dry seasons; these boats bring down lime-stone from the rocks near that place, as I was told. Two locks and one dam would make an open navigation from Gartmore to the Firth of Forth, at all seasons of the year; and were there any trade of consequence up this extensive valley, would be worth the while, independent of a navigable communication between the two seas. One lock ought to be placed opposite Craigforth mill, and the other lock and dam at the ford of Frew; this, with a little clearance of the shoal at Cardross, would make a navigable passage over the same.

From the mouth of the Keltie to Stirling, is about twelve miles, in a straight line, but by the course of the river, appears to be more than twenty. It may seem that this might be helped, by cutting through some of the most remarkable loops, but the surface of the river lies so much within soil, that these cuts, though short, would be required to be so deep, that the advantage gained would be by no means adequate to the expense, nor would the making an entire new canal be so easy a matter as the seeming flatness of the valley would indicate, for, being interspersed with mosses and broad slades, where the burns come down, which are numerous, the surface of the moss is elevated several feet above, and the slades depressed as many below the mean surface; so that what with extra cutting in some places, and extra banking in others, together with the works necessary in crossing the burns to get rid of their waters in rainy seasons, this work would be made very expensive.

From Stirling to Alloa, there is at present an open navigation, but through so winding a passage as is almost without a parallel, it being accounted four miles by

land, and twenty-four by water: some of these loops, I apprehend, it would be worth while to cut, for the improvement of the navigation.

According to this description, it measures by the course of the rivers, &c. from the summit of the bog of Bollat to Alloa, at least forty-eight miles, and from Dumbarton to the summit of the bog twenty-five miles, so that the whole course, from Dumbarton to Alloa, by the loops of the rivers, will be seventy-three miles; and it further appears, that by the most direct passage that can be made, it will be at least forty miles.

COMPARISON OF THE TWO PASSAGES.

From what has been already observed, it is manifest that the Loch Lomond passage is considerably further about than the Carron passage, and that it is at least equally embarrassed with difficulties; the only point, therefore, in which a competition can be supposed, must be on account of expense. In order to bring this matter into a narrow compass, I will suppose the Loch Lomond passage to be done at the least possible expense, in which case the distance, as before mentioned, will be seventy-three miles. The impediments being supposed equal, the difference of expense will lie in two articles, viz. the difference of length of the artificial part of the navigation, and the difference of the lockage. To reduce the difference of expense arising from the difference of length of the artificial part, to the most simple form, I will suppose in favour of the Loch Lomond passage, that the parts of the river to be made navigable, by means of dams, &c. to be the same expense as the same length of canal, though, in general, this kind of work turns out more expensive in such embarrassed situations.

	Miles.
The length of the river Leven, in a right line	4
The river Enrick from Loch Lomond, to the S. W. corner of Dalnair Park, in a right line	5
From hence to the point of departure from the Enrick	2
From thence by canal to the summit of the bog of Bollat	1
	12
From the summit of the bog of Bollat to the nearest part of the river Forth, near Offrings	4
The cuts and dams upon the Forth being reckoned at one mile, will be greatly undervalued	1
Total length of the artificial part in the Loch Lomond passage	17
The Carron passage, measures	27
Difference of length of artificial navigation, in favour of Loch Lomond	10

	Feet	Inches.
The perpendicular height of the summit of the bog of Bollat, above the neap tide high-water surface of the Clyde, at Dumbarton	222	0
The height of the summit of Dolater bog, above high-water neap tides, at Carron shore	147	0
Difference of perpendicular height, in favour of Carron shore	75	
But this difference of perpendicular height in point of lockage will be double	150	

	£.
I estimate the cutting at £1250 per mile, extra banking, bridges, tunnels, towing-paths, and contingent works; therefore ten miles will come to	12,500
The lockage I estimate at £133 per foot; rise or fall; the difference being 150 feet, comes to	15,000
The difference of expense in favour of Carron	£2,500

So that the Loch Lomond passage will cost £2500 more than the Carron passage; is further about by almost forty miles; and will be attended with an additional loss of time in passing, and expense in keeping between thirty and forty locks in repair.

I presume I have now said enough on this head.

FURTHER PARTICULARS RELATING TO THE CARRON PASSAGE.

HAVING already given a general description of the path by which the canal may be conducted from Carron shore to Barns of Clyde, it remains that I now enlarge upon some matters relative to this scheme, not yet sufficiently explained.

First, As to the method of supplying the canal with water. The first and grand principle is to bring a sufficiency of water to the point of partition, which is here in the middle of Dolater bog, between A and B, fig. 2. not only to answer the expense of water in filling the locks on the passage of vessels, and of the constant leakage that will always be, more or less, through the gates thereof, but also to make good any waste that may happen by soakage through the banks, and into the ground where the canal is carried, above soil, or upon an elevated part of the country, or that may arise from the exhalations from the surface, by the sun and winds in dry seasons; and it is very evident that the supplies for all these purposes must depend upon the water brought to the point of partition till other supplies can be brought into the canal at a lower level in aid thereof. Now, the space of canal that I look upon will chiefly depend upon the point of partition for its supply, will be from the falling in of Redburn, a little above Castle Cary Bridge, east, to Inch Belly Bridge, upon the Kelvin, west, which includes a space of 7½ miles; but before we can determine the quantity of water necessary to supply this space, we must first determine the kind of vessels proposed to navigate this canal, and the tonnage of goods that may be supposed to be carried thereon.

With this view I examined the ga boats, which ply upon the Clyde, and are capable of navigating that Firth in all common seasons, and which I apprehend by the same rule would navigate the Firth of Forth, between the canal and the port of Leith, if found requisite so to do. I found that a middling ga boat of fifty-six feet long, stem and stern, seventeen and a half feet wide, and drawing four feet water, will carry at least forty tons, and this I look upon to be the largest size that will be convenient for an artificial navigation. Now, suppose twenty of these boats pass per day, at an average, in the driest seasons, that is, ten each way, and supposing them to go full loaded from the Clyde to the Forth, and half loaded from the Forth to the Clyde, they will carry 600 tons of goods per day, and 4200 tons per week; in which I reckon seven days: for though the boats should not work on Sundays, yet, as the water will be amassing, the capacity of carriage, in point of water, will not be diminished, which will also be the case, though they do not go regularly. But, casting off the 200 tons for accidents and disappointments, and reckoning upon 4000 tons per week, this will amount to 208,000 tons per year, exclusive of what may be further done, when the supply of water is unlimited. The lock duty, exclusive of freight, would, I apprehend, very well bear five shillings per ton; but, at two shillings and six-pence, 208,000 tons, would amount to £26,000 per annum; from hence I would infer, that if we could furnish water in dry seasons for twenty boats per day, there will be water enough at the lowest tonnage that can be supposed, to

raise a much greater annual sum than can be wanted for repairs, and to discharge the interest of the capital to be expended thereon, and in all probability, more water than the trade can possibly want; but I would not have it inferred from hence, that because the canal can carry 208,000 tons per year, that there will be 208,000 tons per year to carry; consequently, the price of tonnage must be fixed upon the probability of carriage, which I leave to the decision of those who are better skilled than I am both in the general trade of this kingdom, and the particular trade of those parts.

Now, it is certain that every vessel in its passage cannot require more than two locksfull of water, out of the canal of partition; one at its entry, the other at its departure, which locksfull of water, will either furnish the same vessel, or some other, with a passage through all the rest; supposing them of no greater perpendicular rise: I say, cannot require more; because, if two vessels meet at a lock, one going down, the other up, they may both pass with one lockfull; but supposing the worst, that is, that every vessel take two locksfull from the canal of partition, the size of the vessels being as before mentioned, will require the locks to be sixty-four feet long, and eighteen feet wide; and supposing the rise at each lock to be three feet from the canal of partition, to Redburn one way, and to Inch Belly Bridge the other, the water necessary for the passage of a vessel will be 3456 cube feet at each lock, at the extremities of the canal of partition, at A and B, and at both 6912, and for twenty boats, 138,290 cube feet per day.—A well-made lock will not leak above its own capacity in twenty-four hours, but as things cannot always be equally in order, we will allow two locksfull per day leakage, and as they may be misused by the carelessness common to watermen, we will allow two more on this account, amounting to 13,824 cube feet, which, added to the lockage, 138,240 cube feet makes 152,064 cube feet of water, to be expended in twenty-four hours. Now, within the limits before mentioned, this will be the whole; for, in regard to soakage, as the canal will be carried in the sink of the valley, and dug out of the solid, it will not be above the common drainage of the country, and, therefore, will be more likely to acquire water by cutting of springs than to lose by soakage. In regard to exhalations, I have observed in respect to ponds, canals, and other stagnant waters of a competent depth, that had no springs, but yet were water-tight, that in the greatest extreme of the late dry summer, the loss never amounted to above ten inches in their perpendicular height before they were replenished by casual rains: now I propose that every part of the canal should be dug one foot deeper than the draught of the water of the boats, by which means the boats will have sufficient freedom to their motion; and the canal will contain within itself a reservoir or magazine for supplying the exhalations.

The next point is, to inquire how this quantity of 152,064 cube feet of water is in dry seasons to be collected, and brought to the summit of Dolater bog every twenty-four hours; and the first thing that presents itself is the burn of Achinclough, which discharges itself into the bog as already mentioned. This burn, according to information I received from the miller at Achinclough, is capable of furnishing water in the dryest seasons sufficient to work his mill 4½ hours per diem; now, from the quantity I found necessary to work the mill, this will amount to 89,343 cube feet per diem.

The burn of Kylsith, by the same kind of examination, at Kylsith mill, I find will deliver 87,003 cube feet in the same time; the sum is 176,346 cube feet that these two burns will furnish in twenty-four hours in the dryest seasons; that is, more by 24,281 cube feet, than as before required, which affords a surplusage of seven locks-

full per diem, to answer contingencies, besides some other supplies that shall be mentioned.

The burn of Kylsith falls into the Kelvin a little below Achinvole, marked R, at a place about twenty feet below the summit of the bog, but as this burn comes down from the high ground, it can be intercepted and carried to the point of partition. The most easy and convenient way of doing this, will be to take it up at the tail of Kylsith mill, and carrying it eastward upon the declining ground, it will cross the ridge of hills to the north-eastward of a place called Craigstones, and fall into the Shawend burn; with which it can easily be carried to the place of destination: from an observation not very minute, it appears to me, that there is a sufficiency of elevation to carry Kylsith burn over into Shawend burn, from the tail of the mill; but should there, upon a more accurate level, prove scarcely enough, yet the purposes hereby intended would not be defeated, as there is a fall of between thirty and forty feet just above the mill, so that by raising the mill wheel, an additional fall of twenty feet might be gained from the tail thereof, without detriment to the mill. Shawend burn is said to afford some water in the dryest seasons; and in common seasons a considerable quantity. At the east end of the bog, at Wineford, a coal-pit drain discharges itself, which affords a constant supply of water, amounting to some locksfull per day: I have not, however, brought these supplies to account, because, it appears from the preceding calculation, that the two burns of Achinclough and Kylsith are of themselves sufficient: I have taken notice of those others, therefore, as a means of supplying deficiency, if any such should happen to arise from unforeseen causes. Nor are those the only ones that can be so applied, because, if it should prove necesary, Redburn, which, together with Achinclough, forms the river Bonnie, a little above Castle Cary Bridge, may easily be brought to the point of partition; for the level of the surface of Redburn, at the point of confluence, is not more than twenty-three feet below the summit of the bog, and distant about a mile, and as Redburn is very rapid, it may be lifted so as to run to the point of partition, without going any considerable distance up the burn. This burn I look upon, from inspection, to be at least as good as either Achinclough or Kylsith burns; so that, together with the reservoirs for water that may be formed both in the bog, and in the hollows of the contiguous hills, from whence these burns proceed, it does not admit of a doubt but that nature has furnished the means of bringing as much water to the point of partition as can possibly be wanted, and that by methods sufficiently simple and easy.

I have mentioned that the space depending upon the waters to be brought to the point of partition, is that between Redburn, east, and Inch Belly Bridge, west; for at all those places the accession of waters, by taking an occasional supply from Redburn, into the canal on one hand, and on the other by taking in the Kelvin at Inch Belly Bridge, will not only countervail any deficiency by leakage or soakage, between their junction with the canal, and its termination each way respectively, but, also, to allow of one foot of greater height in the locks below those points, to avoid too great a multiplicity thereof. By taking the Kelvin into the canal at Inch Belly Bridge, the whole collection of little rills and springs that fall into the Kelvin below the level of Kylsith mill (of which there are several constant ones), will be brought to account, and the communication with the river Loggie, in crossing the same at Kirkintilloch, will be an absolute security against any defect in that branch below the same; so that there is all possible certainty that the canal will be amply supplied from end to end.

Secondly. Having now supplied the canal with water, it remains with me to shew how this is to be done without injury to the mills and other works upon the rivers Carron and Kelvin; which, below the mouth of the Bonnie on the Carron, and

below Garscud Bridge on the Kelvin, are not only valuable, but said to be in want of water in dry seasons.

In order to put this matter in a clear light, let us examine for how much water we have, by the preceding scheme, taking credit of the aforesaid rivers; and it will appear that we have taken the burns of Achinclough and Kylsith, with so much from the others as shall be wanting to make up the deficiencies of the former, in supplying the lower parts of the canal with water.

	Cubic Feet.
For supplying the locks of three feet rise between Redburn and Inch Belly Bridge, we shall want as much as before estimated per day	138,240
Now, if the locks were proposed to be of three feet all the way, the same water would serve them quite through; but, being proposed of four feet below those points, they will require an addition of one-third of the foregoing quantity, which will amount to	46,080
The leakage of the locks were before estimated at	13,824
Total required	198,144
The Achinclough and Kylsith burns supply	176,346
Deficiency to be taken from Redburn, Kelvin, and Loggie	21,798

which deficiency is nearly one-eighth of the whole quantity, supplied by the two burns; that is, as those two burns are said to turn their respective mills, 4½ and four hours, which is together 8½ hours, as much water must be taken from the other rivulets as will turn a common burn mill, with an overshot wheel, a little more than an hour, in order to make good the surplusage above the two burns.

I have not brought the exhalations, and soakage through the banks, into the above account; for, with regard to exhalations, as the whole is proposed to be dug to an extra depth, in order to take in a surplus quantity of water in time of rains (at which times the mills have water enough to spare), this may be laid out of the account: and in regard to soakage, though a supply for that purpose will be wanted from the burns, yet as that will return again into the rivers, it is not lost to the mills; and though some part of the soakage may fall into different valleys, yet as it must be expected, that the rills and springs, which will be intersected by the canal, that used to run into those valleys, will counter-balance the soakage of these parts of the canal, there will still be no water lost to the mills on account of soakage; the quantity then that we are to restore, is the value of the two burns, one equal to Achinclough, and the other to Kylsith, and one-eighth part more of each respectively; and this may be done by intercepting and turning some waters that fall into other rivers, into the Carron and Kelvin.

Having, for this purpose, examined the country, I find that a part of the river Enrick, near its source, may be intercepted a little above a place called Randeford, which being carried to the west of the ruins of St. John the Graham's castle, and passing by a place called Bog Side, through a morass, lies nearly upon a level between the two rivers, will fall into the Carron; the place is marked in the general map, fig. 1. with a line A. The waters of Enrick, at the point where it is proposed to be turned, appear to be more than double those of the burn of Achinclough; but if unforseen occasion should happen to require a further supply, it may be procured by turning the upper part of the burn of Gonakin into Carron, which rises from springs in Campsie Fells, and now falls into Enrick; this is marked with a dotted line B. With respect to Kelvin, the water of Glazert, which falls into Kelvin, and the water of Blain, which falls into Enrick, have their source near the same place, there being a continued flat valley between them, like the Kelvin and Bonnie: near the point of partition of the waters, is a remarkable cascade, or cataract, called the spout of Ballagin, marked

D, which, falling from the south side of Campsie Fells, immediately forms a considerable burn, whose general course is into the waters of Blain, but is so critically situated, that in time of floods, a part of its waters is sometimes discharged into the Glazert, and with a very little trouble would be made to do so constantly; this is marked in the general map by D. This burn appears equal to the burn at Kylsith mills, and, therefore, may be substituted in its stead; and the eighth part thereof, still wanting, may be made good by intercepting a number of springs which issue out of the hills on both sides at a sufficient elevation to be carried over the point of partition into the Glazert, which now falls into the waters of Blain. Those springs may be intercepted on the north side, if occasion should require, almost as far as Duntraith.

To this method of supply it may possibly be objected, that in order to repay the mills on Carron and Kelvin, I have robbed those on the Enrick and Blain: but here I must observe, that where there is more work than water, to take away a part thereof, though small, is a proportionable loss; but to take away a small quantity of water, where there is much more water than work, is no loss at all.

Upon the water of Enrick and Blain, there are no mills of any consequence; the most considerable are those at the Pot of Gartness, Y, which, as I am informed, are far from being fully worked, and, if they were, as a considerable part of the fall there is unemployed, their power might be greatly increased, though the quantity of water were a little diminished; and it must be remembered, that the whole quantity wanted hence, is only an equivalent to Achinclough burn, and one-eighth more, which burn turns an overshot mill 4½ hours per day; whereas the river Enrick, at the Pot of Gartness, is a considerable river, and has a fall there, as before observed, of between 30 and 40 feet. However, to cut of all altercation respecting mills, the trustees to be appointed for the execution of this scheme may safely engage to give the mills on the Carron and Kelvin as much water in dry seasons as they take away, and to make good all damages that may accrue to the others. I shall now more particularly describe some things, which, though hinted at in the general description of the Carron passage, have not been fully explained.

3dly. The size of the canal I propose to be 24 feet in the bottom; and the sides to be sloped, at a medium, in the proportion of 5 to 3; that is, for every 3 feet depth to widen 5 feet on each side, or 10 feet on both sides; to be 5 feet deep of water, and at a medium 7 feet deep within soil, so that its mean width, at the surface of the water will be 40 feet 8 inches, and to be made wider at convenient places, and at proper distances, for vessels to pass each other. To make the canal less for boats of 17½ feet wide, drawing 4 feet water, would make them draw hard, and to make it larger would induce an unnecessary expense. The locks I would propose not to exceed 4 feet rise at each, in order to save water in working them, and if made with less rises, would be too troublesome on account of their number, only between Redburn and Inch Belly Bridge, as water may there be more scarce, I have proposed them of 3 feet rise each.

The several hollows that the canal will intersect in its passage from Camelton to Castle Cary Bridge, I have proposed to pass by banking across, so as to raise the water in the same up to the level of the canal: the deepest of these is the first to the west of Camelton, marked G in the plan of the canal, fig. 2, which is about 18 feet deep in the deepest part, and 70 yards wide at the top; the others are less considerable, except at Bonnie mill, which I have proposed to cross on arches; this will be about 30 feet deep, and 70 yards wide at top, but the arches need not extend above 30 yards, the rest may be done by wharfing and banking. The aqueduct bridge that will be wanted in crossing the river Bonnie just below Castle Cary Bridge, will be

necessary, not on account of the depth of the valley, but to give the river a free passage under the canal; four small arches of 10 feet each, will here be sufficient; but if it be thought more eligible in the execution, the crossing the river may be effected by forming a dam or weir across the river Bonnie, but this will destroy the fall of Castle Cary mill. From hence to Dolater bog there are no difficulties.

The canal of partition extending about $1\frac{1}{2}$ mile between the two locks at its extremes, marked A and B in the plan, I would propose to be dug out 50 feet wide at bottom, with slopes as before, which will form a reservoir for water, capable of holding three days' supply upon a foot in depth: this is as much as can be wanted, especially at first, till the canal has got a large trade upon it, and if any thing further should appear necessary, especially after the Redburn is brought to the point of partition, I would advise it to be done by banking in a part of the bog, by which means it will be formed sufficiently high to yield its contents into the canal of partition by a sluice, as occasion may require; there will be here included a space of twenty Scots acres, which, at 4 feet deep, will contain a supply of twenty-five days.

From hence to Inch Belly Bridge there is no difficulty. Below this bridge I propose to put a dam at K, in order to force the water at a proper elevation into the canal K L, which is intended to drop into the Loggie above the mill-dam at L; which dam will again force the water into the canal L M, and which, by proper locks, conducts us into the river at Calder Bridge. A little below this bridge, in like manner, I propose a dam or weir M, to throw a proper body of water into the canal M N, by which we are conducted to the Allander, where the two passages divide, by either of which we may pass upon the same level into the valley leading down to Grascuddon, one up the Allander, the other by Canny's burn into St. German's Loch; a little below which, both passages would unite in the same point at O. It remains, therefore, to give a reason, why, of the two passages, I prefer the latter.

For this purpose, having taken a level from the surface of the water of the Kelvin, just below Calder Bridge, to the summit of each high ground, I found them to differ but inconsiderably in their perpendicular height, the summit of the high ground by the Allander passage being 32, and that by the Canny's burn passage being 33 feet above the said water: I likewise, upon examination, found the base of the hill in the Allander passage, to be $1\frac{1}{2}$ mile, or 12 furlongs, that would require an extra depth of cut; 6 furlongs of which would be above 15 feet deep; whereas, in the Canny's burn passage, the whole length that would require extra cutting is not above $2\frac{1}{2}$ furlongs; and there is not quite 1 furlong that would be above 15 feet deep. If nature had furnished no other passage than that of the Allander, something might be done towards lessening the expense by retrograde locks, but as this would cause hinderance of time, as well as an additional cost in the article of lockage, there appears to me no way by which it can be done either so well, or so cheaply as by the Canny's burn passage.

Where the depth exceeds 15 feet, which will not be above 200 yards, I would propose the passage to be by a vault under ground; and though the matter of the hill seems to be a loose gravel, yet I apprehend the means are not very difficult by which it might be perforated. I would begin at an end and open the ground from the top, the same width I intended it at bottom, that is, 18 feet, like the locks, with an allowance for the thickness of the walls; and cutting down the sides perpendicular, would shore the same from side to side with boards, beams, and braces of ordinary Scotch fir, these keeping up the matter till the arch is built the shores that are above the arch may be taken away, and replaced as the work advances, and the cross braces

that interfere with the walls of the arch may be walled in, and afterwards cut out when the whole is completed.

From St. German's Loch, I would carry the canal upon the decline of the hill upon such a level as, with a little extra cutting, to pass the high ground that lies on the south of the mill-dam of Grascuddon; this I propose, in case it should be not agreeable to the lord of Grascuddon to carry the navigation through this dam, which is an ornamental piece of water, with planting and walks round it; otherwise, this part of the canal will be more easily done by passing through this piece of water. From Grascuddon mill-dam there is between 20 and 30 feet fall in a little space; but from thence to the Clyde the ground lies upon a gradual descent, in which there is no difficulty.

At entering the Clyde, a jetty, formed of rubble stone, may be necessary to keep clear the tail of the cut.

Fourthly. With respect to the number of locks: this depends upon the perpendicular height of the whole, and the perpendicular rise proposed to each lock. The perpendicular rise of the whole I make to be 147 feet, from the high-water surface at a neap-tide at Carron shore, to the summit of Dolater bog. But as I would propose to keep the surface of the canal somewhat below the surface of the land there, we will call the perpendicular ascent 145 feet. In this I cannot pretend to be exact, for the violent squalls of wind and rain that occurred the whole time of the survey, made it exceedingly difficult and troublesome to manage any instrument for this purpose. It is possible I may have erred some feet in the whole perpendicular; but, as from the direction in which the wind generally blew, I am inclined to believe that what error there may be, is by exceeding the truth, if it should be found, upon re-examination, to be 5 feet less than I have made it (or even double that quantity), it will make no alteration in the general design, nor produce any other effect than the saving so much in the lockage of that perpendicular; and hence it appears, that an exact knowledge of the perpendicular is not at present necessary to determine the practicability of the scheme.

It may, likewise, be questioned, whether the perpendicular elevation of Dolater bog be the same above the Firth of Clyde as it is above the Firth of Forth; and it is possible it may not; but as water undisturbed naturally places itself upon a level, and as the disturbing causes, viz. the wind and tides, frequently act in opposite directions, we may be assured, that the mean height of the two seas is not so different as to make any material difference in the scheme proposed. Accounting, therefore, the perpendicular height both ways 145 feet, we shall have the number of locks as follows:

	No. of Locks.
From Carron shore to the intended level of the canal above Camelton, I make to be 108 feet, which, at 4 feet each, requires	27
From thence to Castle Cary Bridge, the canal being upon a level, will require none, but from Castle Cary Bridge to Redburn, there is a rise of 16 feet, which, at 4 feet each, will take	4
From Redburn into the canal of partition, being 21 feet, at 3 feet each, will require	7
No. of locks from Carron shore to the point of partition	38
From the canal of partition to Inch Belly Bridge, I estimate the fall at thirty-six feet, this, at three feet each, will take	12
From thence to the Clyde there will remain 109 feet, which, at four feet each, will take	27
Number of locks in the whole	77

N.B. The above is the greatest number that can be required, for if, in the execution, it should appear that the supply of water should turn out more liberal, or a

less number of vessels expected to navigate, than I have supposed, then some expense may be saved by making the rises of the locks greater in general; and without preserving a strict equality, by which means they might be made more readily to suit the ground: it must, however, be observed, that the highest lock determines the quantity of water to be used; for were there but one lock of eight feet in the whole collection, this would occasion as great a consumption of water, as if they were all of the same height; unless an extra supply could be brought to this lock, to set against the extra quantity.

Fifthly. Wherever the canal is by banking held up above soil, that is, above the natural surface of the land, it is proposed to cut back-drains behind such banks, to receive any leakage that otherwise might hurt the adjacent soil, and to conduct the same to some common watercourse; also to lay tunnels under the bottom of the cut to communicate such watercourses across the same as require to be preserved, or whose elevation may not suit to be brought into the canal. Also to make bridges in proper places over the canal, for communication between such properties as shall be severed by the same; and to make gates upon the towing-paths between every fence, and double gates, if required, for the divisions between different properties, with over-falls in proper places for discharging the overplus waters, and whatever else may appear necessary for preserving each person's property as nearly as may be in the same state as before the execution of this project.

Sixthly. It is very difficult, if not impossible, upon one survey, to take in every view of a subject so complicated; I, therefore, consider what I have reported as shewing the general practicability of the proposed scheme, with one method of executing the same; but as it is most probable that many improvements may be made whenever it is reconsidered for execution, the trustees appointed should be invested with sufficient power for doing whatever might appear necessary.

ESTIMATE OF THE EXPENSE.

	£.
The canal being twenty-four feet, mean width, in the bottom, and seven feet mean depth, with slopes as five to three, the width at top will be forty-eight feet, and mean width, thirty-six feet, will contain twenty-eight cube yards in each yard running, and in a mile 49,280 cube yards of digging, which, at 3*d.* per yard, come to 616*l.* per mile, and for twenty-seven miles in length, to	16,632
To extra digging in the canal of partition, to make it fifty feet bottom, 53,308 yards, at 3*d.*	667
For extra work in making several passing places, and some additional measure in turning the angles, allow upon the whole the value of one mile.....	616
The canal being forty-eight feet top, allow the same width for the banks on each side, that is, forty-eight yards in breadth over all, which makes in one mile 84,480 square yards, which is 15½ Scotch acres nearly; and for twenty-seven miles, 418½ acres, which, supposing them to be purchased, at a medium, at 20*l.* an acre, come to.....	8,370
N.B. The greatest part of the tract is corn ground; but as there is a considerable quantity of pasture and moor grounds of small value, and the banks being possessed by the owners of the respective lands, are generally supposed to be of half value, I suppose the above price, at a medium, may be sufficient; if otherwise, the extra value must be added.	
Besides what is immediately occupied by the canal and its banks, land will be wanted for conveniencies, trenches, reservoirs, &c. which in the whole may amount to twenty acres	400
Carried over	26,685

	£.
Brought over	26,685
The number of locks being seventy-seven, 400*l.* each, amount to	30,800
To extra digging in passing a narrow gripe, between two rising grounds a little to the south-westward of Mungull's house	100
To extra banking across six haughs, or hollows, between that place and Bonnie mills, at an average 100*l.* each	600
To an aqueduct bridge in passing Bonnie mill-burn, and extra banking up the same, with an over-fall for discharging the overplus water of the canal	1000
To extra work in passing Seabeg's wood, Trannock burn, Acre burn, and some other haughs and risings, from thence to Castle Cary Bridge	400
To an aqueduct bridge for passing the river Bonnie, near Castle Cary Bridge, and extra banking there	800
To a shuttle for taking in water, as occasion may require, from Redburn, and an over-fall for discharging the overplus water	20
To two miles of trenching, in bringing Kylsith burn, together with Shawen burn, into the canal of partition, which, at 1*s.* per yard running, comes to 176*l.*; and allowing 74*l.* for extra cutting, with such small tunnels and bridges as may be wanted under and over the same, together with a shuttle and over-fall for taking in the water, and discharging the superfluous ditto, this work will come to	250
To building a dam or weir across the Kelvin below Inch Belly Bridge, with proper shuttles for drawing the water off occasionally	500
To building a ditto below Calder Bridge	500
To an aqueduct bridge for crossing the river Allander, and extra banking there	300
To extra work in piercing and vaulting a passage through the high ground, between Canny's burn and St. German's Loch	1200
To extra work in passing Grascuddon	100
To extra work in making a jetty to defend the mouth of the canal, and clearing the passage into Clyde	150
To five public road bridges, viz. at the road from Falkirk to Carron, at Camelton, at Castle Cary, at Canny's burn, and at Yockner, at 100*l.* each	500
To twenty-one bridges, where the lesser roads intersect the canal, at 75*l.* each	1575
To private bridges that may be wanting for preserving the communications between the lands, No. 28, making, with the public road bridges, at an average, two in a mile, at 50*l.* each	1400
To thirteen large tunnels for communicating the lesser brooks under the canal, at 40*l.* each	520
To sixty-eight small tunnels for preserving watercourses, making, together with the large ones, at an average, three in a mile, at 10*l.* each	680
To making towing-paths, back-drains, gates, towing-bridges, &c. at per mile, 20*l.*	540
To bringing the water of Enrick from a little above Randeford, into Carron	150
To bringing the burn of Ballagin, with some springs rising out of the hills to the west of the spout of Ballagin, into Kelvin	100
To temporary damages to lands and mills, impediments and works, unforeseen accidents, engines, utensils, and supervising	10,000
Total,	£.78,970

APPENDIX.

As the noblest work of the kind that ever has been executed, viz. the Canal Royal of Languedoc, has been generally esteemed not to answer the expense, this will undoubtedly be made an argument against the present proposition; I shall, therefore, oppose some matters of fact relating to the French canal by way of parallel.

Canal of Languedoc.

Length of the canal between Port de Cette, on the Mediterranean, and Toulouse, is 152 English miles, besides a river

Canal proposed between the Forth and Clyde.

Length of the canal between the Carron shore and Barns of Clyde, is 27 English miles. Sea vessels going up to

navigation from Toulouse to Bordeaux, which is above 100 miles more, so that the whole length of inland navigation is above 250 English miles between the sea ports.

Suppose the vessels make way at an average, 1½ mile an hour, the passage will take fourteen days of twelve hours each.

The perpendicular height of the point of partition is 639 English feet above the two seas.

The canal is navigated by 100 locks, of above eight feet rise each.

The expense of this undertaking has been 612,500*l.* sterling.

This work is still incomplete, by reason of shoals in the river Garonne, below Toulouse, which, in dry seasons, greatly interrupts vessels; to carry the canal below which, as the only remedy, is estimated to cost 43,750*l.*

Carron shore, and to Dumbarton, the distance of which by the canal will be 33 miles, but reckoning from port Glasgow to Leith, the distance will not exceed 70 English miles.

Suppose the vessels to make way, at an average, 1½ mile per hour, the passage will be but four days of twelve hours each.

The perpendicular height of the point of partition in the proposed canal is 145 feet.

This canal is to be navigated by 77 locks, of between three and four feet rise each.

The expense of this undertaking is estimated at 78,970*l.*

This canal drops into the rivers Carron and Clyde, in the tides-way, in places where there will be no obstruction to the vessels proposed to navigate the canals in the dryest seasons, at high water, to proceed upon their voyage to their respective sea ports.

Now, if it may be admitted, that as great a trade is likely to be carried on between the Forth and Clyde, where the sea navigation is long and dangerous, the inland short and easy, as between the Gulf of Lyons and the Bay of Biscay, where the sea navigation is open at all times, though long, the inland navigation tedious, and, at some times, almost impassable for want of water over the shoals in the river; the inference is very plain; that the same tolls which will hardly keep the French canal in repair, will make this a very beneficial undertaking to the British adventurers.

POSTSCRIPT.

First. On further considering the matter of the foregoing Report, I am of opinion it will be eligible to carry Redburn into the canal of partition, not as a subsidiary expedient in case of need, but to be applied in the first construction; the charge thereof will be amply recompensed by the omission of five locks between Redburn and Inch Belly Bridge; for the three feet locks proposed in that district may then be four feet, the same as all the rest; and it will appear from what has been said above, that the water expended on the whole, will be precisely the same: so that then the number of locks will be thirty-six each way, and, in the whole, seventy-two.

Secondly. Since the foregoing Report, with the preceding article, by way of postscript, was delivered to the honourable the Trustees for Fisheries and Manufactures in Scotland, Mr. Smeaton has discovered that, notwithstanding the care and pains he took to be correct, he has committed an error, in supposing the Scotch chain, with which the measures of the length of the tract for the land were taken, to consist of seventy feet each, whereas, in reality, it consists of seventy-four; this difference will not, however, in any respect affect the general principles upon which the preceding scheme is built, nor the estimate in any articles, except where the length of the canal

is concerned. This length now appears to be 28¼ miles, instead of 27, as before supposed, and this addition of 1¼ mile, will affect the estimate in the whole, 1322*l.* 10*s.* but as, by the foregoing article of postscript, there will be a saving of at least 1600*l.* the estimate upon the whole will be rather less than greater, in which there is ample allowance for contingencies.

N.B. The true measure of the canal is 2010 Scots chains, which, at seventy feet per chain, comes to twenty-six miles, five furlongs, seven poles, 4½; this, for a round number, was called twenty-seven miles, but at seventy-four feet to the chain, makes almost 28¼ English miles.

J. SMEATON.

COMPARATIVE ESTIMATE

Between a Canal from Forth to Clyde, for Vessels of Forty Tons, and for those proposed in the contracted Scheme.

	£.	s.	d.
Estimate, as it stands in Mr. SMEATON's Report	78,970	0	0
To this add the expense upon additional length, as mentioned in the postscript	1,322	10	0
Sum total	80,292	10	0
Deduct as follows:			
Saving in making of thirty-six locks, of eight feet high, instead of seventy-two of four feet	9,200	0	0
Saving by half a foot depth of canal	1,678	0	0
Ditto, by extra digging, in widening the canal of partition, which, as there will be plenty of water in proportion to the work, will be unnecessary	667	0	0
	11,545	0	0
	68,647	10	0
Saving, by making thirty-six locks of ten feet wide instead of eighteen, at 75*l.* each	2,700	0	0
Ditto, by making the canal twelve feet narrower, and one foot shallower, than supposed in my estimate, by which means it will be equally accommodated to boats of nine and and a half, as I have supposed for seventeen and a half	8,076	0	0
Saving, by purchase of lands, the whole width being thirty-two feet instead of forty-eight, one-third must be deducted, amounting to	2,918	10	0
Ditto, by bridges, tunnels, and other extra articles, amounting in the whole to 9,095*l.*, one-sixth thereof I suppose will be saved	1,516	0	0
	15,211	0	0
The reduction of several articles, as before	15,211	0	0
Reduction of 10,000*l.* allowed for contingencies, in proportion to the above reduction	2,594	0	0
	17,805	0	0
The first estimate reduced on account of water	68,647	10	0
Difference in the value of a canal, according to the dimensions proposed for a little one	50,842	10	0

This sum is 100*l.* too little, but was so delivered in.

Queries proposed by the Right Honourable Lord CATHCART.

1. Is not the best way to render the Leven navigable, the removal of a bar where it issues out of Loch Lomond, which would lower the lake ten feet perpendicular, and reduce the fall into the Leven ten feet, which would facilitate the making two locks and dams to complete the navigation?

2. Is it not probable that the grounds gained off the lake in this manner would do more than answer the expense of removing the bar? and is not 4125*l.* a proper charge for ten feet of lockage, and two and a half miles of artificial navigation in the Leven?

3. Is it not probable, that were the channel of the Forth straightened from Alloa to Offring, the tide would rise to that place, as it is but eight feet above the level of the present neap-tide above Stirling Bridge; and the tide which comes from Leith to Alloa in three quarters of an hour, takes the same length of time to go up to Stirling Pier, which is not four miles in a straight line, and a quarter of an hour from thence to the Bridge, which is but a few yards when straightened? And would not the ground gained by this operation in all probability answer the expense of it?

These rivers, made navigable either by the method proposed, or some better expedient, it is to be considered, how the junction of the two seas can best be made: whether, by the Carron canal, or joining the Forth to the Enrick and Leven, or by carrying goods over land from Forth to Enrick?

Is it not better to cut a canal from the upper part of Leven to Oatter, along the ground which will be uncovered by lowering the lake, than to navigate the lake, which is tempestuous, and the Enrick, which will be difficult to enter at the mouth after the lake is lowered?

4. Does it appear impossible to run a level drift from that part of the Enrick where he proposed to insert his canals under the summit of Bollat, and issuing out of the hill on the side next the Forth, and pointing towards Cardross, the said drift not exceeding two miles in length, and gaining one hundred and twenty-nine feet of perpendicular height.

The reason for believing this possible is the description of the ground in Mr. SMEATON'S Report, which says, the distance from the Enrick to the summit of Bollat is one mile, the height one hundred and twenty-nine feet; that from the summit the ground falls towards the Forth, and it is apprehended in a proportion not unlike that in which it rises from Enrick; in that case the drift would be the base of a triangle, the sides of which would be two miles, and therefore would itself be less than two miles.

5. Might not two hundred and two feet of height be saved by a drift of four miles from the level of Oatter, and coming out somewhere in the channel of Keltie burn?

6. What ought the dimensions of such drifts to be, in order to carry the canal through the hill at one or the other of these points, and what, at an average, might be the expense?

The rubbish will certainly be drawn up to the surface through pits made for that purpose, which will not be deep; and, therefore, it is apprehended, the length of the drift ought not to increase the proportion of the expense; it is also imagined, in such a drift, a towing-path would be unnecessary.

7. Would it not be a shortening of the navigation, both in the Bollat and Oatter passages, to join the Forth at Cardross rather than Offring?

8. Supposing that the public, or that private adventurers were to undertake the Carron canal, how long would it probably be before the said canal could be navigated;

and what would be the tolls, or rather, what would be the sum of the toll, necessary for reimbursement and repairs?

9. Supposing the Oatter passage to be undertaken, how soon would it be practised?

10. If the Bollat or Keltie passage were to be made choice of, the Oatter passage would be a part of either; but though the Carron passage were pitched upon, would the temporary advantage, and the eventual resource of the Oatter passage, in case of accidents in the Carron canal, together with the toll which would arise from it before the Carron canal could be finished, be proper and safe motives for laying out £12,000 upon it?

11. How many men and horses are required to draw a ga boat of forty tons?

Answer to the Queries proposed by the Right Honourable the Earl of CATHCART *to* JOHN SMEATON, *Engineer.*

To the First. I apprehend it would be a very difficult and expensive piece of work to deepen the channel of the Leven, so as to reduce the water of Loch Lomond ten feet, because the water of the loch is not held up by any one single shoal, but by a succession of shoals from the mouth of the loch, to within a mile of Dumbarton, all of which I apprehend must be deepened in different degrees, in order to produce the desired effect. There is, indeed, a bar or shoal in the mouth of the lake, which would pen the water, in case the shoal next below the boat of Balloch was removed, which now pens the water over the shoal at the entrance; and from the extension of width in that place, the water is nearly stagnant: but, suppose both these shoals removed, the water would still remain penned up by the natural bottom of the river, which is in general shallow from thence quite to the tides-way; and supposing the whole cleared away to ten feet below the uppermost shoal, unless the section of the river were very much increased, the natural declivity of the surface, requisite for discharging so great a quantity of water, would still produce a pen upon the water of the loch.

The deepening of rivers for any extent I have found a very tedious and expensive piece of work; and, in short, I see no means of reducing the water of the loch at the same, or, indeed, any thing near the same expense, as making it navigable by locks and dams.

Secondly. How far it might answer with respect to the drainage of the bordering lands, I cannot be a judge, unless I know the quantity and value of the lands that would be uncovered by a certain number of feet reduction, having never seen any part of the coast, except about the mouths of Leven and Enrick; but it is probable that if a quantity of land were drained hereby, the land-owners would, with great difficulty, be brought to pay for the improvements: £4125 is the average expense of ten feet of lockage for $2\frac{1}{2}$ miles of artificial navigation; but I am of opinion, double that sum would not draw off ten feet water from the surface of the loch, nor would this lockage be saved, if the navigation were carried further, for what is subtracted below must be added above.

Thirdly. But I apprehend the gained lands would by no means defray the expense of making the cuts; because it would be some years before the old loops would become land, and a good deal of present land would be converted into water;

besides, the great depth of cutting required, would make the work turn out a greater expense than the making a new canal for navigation only from Offrings to Alloa.

This may appear, at first sight, a paradoxical position; but if it be considered that the surface of the water in the channel of the Forth, above Craigforth mill, is in general 10 feet within soil, and I suppose in general 20 feet depth of water, the new cuts would in general be 20 feet deep to make them equivalent with the old river, which I take from view to be 80 feet wide at a medium, and, as I suppose, at least one-third must be new cut to make it tolerably straight,—the expense would be much greater, width and depth considered, together with the drainage of the water for what lies below the river's surface, than digging a new canal sufficient in width and depth for the purposes of navigation only. It, perhaps, may be imagined, that digging the cuts of small dimensions, and down to the water's surface at first, may suffice, and that the current will wear out the cores below water, and widen the channels; but though this might be the case between Alloa and Stirling, where the tide runs slow, yet above it would be so checked by those narrow obstructions, that the water being obliged to follow chiefly the old course, would be spent in the meanderings, and the proposed effect destroyed; and, as the reflow of the waters from the country would, in like manner, take that course which, upon the whole, would be easiest, it would probably be many years before the new cuts would be wholly converted into a current river, unless the old loops were entirely shut up by dams, which would still greatly increase the expense.

4th, 5th, 6th, and 7thly. It is difficult to say what cannot be conquered by art, industry, length of time, and unlimited expense, except such things as are impossible in nature, of which kind I do not reckon the piercing the hill of Bollat, or that between Lomond and Keltie, with a navigable passage; but this kind of work generally turns out so very expensive, and so very uncertain in its expense, that I think it should not be undertaken but in cases of absolute necessity. That it will be a great and expensive work to make a navigable canal, which must be at least 20 feet wide, and at least 2 miles under ground, we are very sure, and the most eligible case of it is where there is a free-stone rock sufficiently soft to make it work easy, and sufficiently compact to make it stand without supporting; in case it is softer, so as to make it necessary to arch it, it greatly adds to the expense, but in case it should prove gravel, or any other loose kind of matter, it will be very difficult to get it to stand, till it can be supported by an arch; and if a running sand, so far as I am acquainted, impossible, without opening it from the top, which, though not impracticable at a great depth, is excessively expensive: on the other hand, if it should turn out a hard whinstone rock, so as not to be worked without blasting, the work would not only go on very slow, but vastly expensive, one furlong of which, or a running sand, might overset the undertaking after the rest had been successfully executed.—Drains for coal-pits or mines are much more easily managed, because, being of small dimensions, if of soft matter, they are more easily made to stand till supported, and if of middling or hard, there is less matter to cut.

In the canal of Languedoc, a hill was pierced for the navigation to pass, and made wide enough for a horse-path by the side of it. The passage was pierced through a soft rock, thought at first sufficiently firm to stand by itself, but has since been obliged to be supported by an arch, as I have been informed; what might be the cost of it I know not, but this is certain, that though the extent in our measure be not above 256 yards, yet it is accounted one of the prodigies of that very expensive undertaking. The Duke of Bridgwater has lately made the drain of his colliery navigable, and it is carried upon the same level as his canal; but the subterraneous navigation is only

5½ feet in width; and they were near two years in advancing it half a mile, though no part of it needed blowing: yet many parts were obliged to be supported by walls and an arch of brick: what the particular expense has been, I have not been informed, but imagine it not a trifle, nor is it in any degree to be compared with one near four times the width.—To pretend to give an estimate for a work of this kind without any data of quality of soil, which it is not easy to know beforehand, would be so very vague, that I can hardly tell how to set pen to paper in the way of calculation. It may be imagined, perhaps, that a hole, pierced the size of the Duke of Bridgwater's, might answer the end, but the inconvenience of twice altering the bulk, with the expenses contingent thereon, will be considered under another head.

Eighthly. I apprehend that, supposing as many men could be set to work as could conveniently be properly superintended, the Carron passage might be completed in six, or, at most, seven years; but the difficulty of supporting and maintaining the necessary number of men (suppose 250) upon the works, in the parts of the country where any of the passages are practicable, is an article of consideration; for if they were obliged to be lodged in barracks, the charge of building and removing them will be a further article of expense.

As to the money to be raised by way of toll, 4000*l.* per annum is the interest of 80,000*l.* at 5 per cent, but if undertaken by private adventurers, it should be by no means limited to that sum, as has been done in most of the late Navigation Acts passed for England; but that, if the tolls will bear it, to give the adventurers the prospect of making 10 per cent: this not to be exceeded; but I apprehend absolutely requisite, in order to draw the necessary supplies out of private pockets. In this light, it will never be practicable to reimburse the principal; because, if it affords less than 5 per cent, the means are wanting, and if more, unjust,* nor, indeed, is there any reason for it, because the increase of tolls to be taken in order to produce the reimbursement, must be an additional load laid upon the present generation, who are supposed to contribute the whole, in order to ease the succeeding, who will have the benefit of this great work done to their hands, and only have to raise the interest to maintain and support it, which the benefit their trade will receive will insensibly do.—But if done at the public expense, then I suppose it will be thought equitable that the public money should be reimbursed, and in order that it should be done in some reasonable time, the tolls should clear at least 8000*l.* per annum.

With respect to repairs, they would greatly depend upon the first execution; but suppose this done reasonably well, as I have supposed in my estimate, I look upon it, after every thing is completed, that two gangs of ten men each, with an overseer to each gang, and a general surveyor of the works over them, will keep the works in order as to common repairs.

This I have fully stated in the enclosed copy, of an estimate I have drawn out for the service of the Board of Trustees, which amounts at the utmost to 1600*l.* per annum, supposing that provision is made from the first, for the great repairs that in time must be wanted; but if the current expenses only are raised at first, and the other committed to the increase of trade, that must in a manner necessarily take place, then the sum of 1136*l.* per annum is the sum required.

Ninthly. I suppose the necessaries for the Oatter passage could not be executed in less than three summers, as the first is commonly consumed in getting the works in motion.

* If I expose my money to loss upon the uncertain prospect of gain, it is apprehended to be unjust to pay off the winning stake, as the tolls may be lowered in proportion.

Tenthly. I think, from what has been already advanced upon the former heads, that it would be by no means worth the while to complete the Oatter passage, with a view to serve as a temporary expedient till the Carron passage is perfected, for before the trade could get into a settled tract at Oatter passage, the Carron passage would be completed, and, if expected, would hinder the merchants from turning their attention so effectually upon the benefits that might accrue from the other; for though it might be very eligible, upon a separate plan, to make both the rivers Leven and Forth navigable, yet to effect a communication over land, two additional large warehouses, with additional clerks for the receipts and deliveries, must be planted at the head of each, and all the apparatus necessary for land-carriage must be provided, all which in a great measure would be useless when the Carron passage was completed: and as to serving in case of accident, there is hardly any accident that can happen in the common course of things, but would be sooner repaired than the hands and apparatus necessary in the other passage could be got in motion: for supposing a lock wanted rebuilding, which is the greatest stoppage that can be expected, the work is not begun till every thing is ready, and then vessels being planted on both sides, the goods are delivered over from one to another, which is certainly much less trouble than to employ two warehouses, two clerks, and a land-carriage of five or six miles between; nay, it is much to be questioned, whether with such an interruption of the water-carriage, goods would not be carried cheaper by land the whole way; for suppose the Carron passage interrupted by a space of five or six miles in the middle, which could not be made navigable, I apprehend that goods could be carried cheaper by land the whole length, than by this compound carriage; for the altering the bulk is not only a great expense and loss of time, but by interrupting the certainty of the delivery, much less eligible to merchants; for, besides the expense of two additional warehouses as before stated, there will be the loading and unloading of a vessel, and the loading and unloading of the land-carriage extra in this method of conveyance, and for want of carriages and vessels keeping exact time with each other, neglect of clerks, and the like, if a merchant puts a quantity of goods on board at one end of the canal together, he never could be certain that they would be delivered together at the other end, or in due time.

An experiment was tried in our river this winter: the town of Brighouse, at the present head of the navigation, fetch their coals by land-carriage five miles, from a place within half a mile of the river: some cargoes of coals were brought up by water, and though the tolls upon coals are but one quarter of merchant's goods, yet they could not deliver them cheaper than by land-carriage, for the loading and carriage down to the river side, and the loading and carriage from the river to people's houses, together with freight and tolls, made the coals rather dearer than if fetched by land-carriage from the pits; and yet the tolls were no more than one half-penny per ton per mile.

Eleventh. I apprehend two men and a boy, two horses and a driver, will be necessary to navigate a ga boat of 40 tons.

ESTIMATE

Of the Expense attending the maintaining and preserving of the Canal from Forth to Clyde, by way of Carron Water, and also for collecting the Tolls thereof.

	£.	s.	d.
To sixteen labourers, at 1*s.* per day each (or their equivalent in men whose labour is reckoned at a different rate), their wages per annum will be 15*l.* 12*s.* each, and for sixteen	249	12	0
To two masons and two carpenters, at 1*s.* 6*d.* per day each (or their equivalent), which comes to 23*l.* 8*s.* per year each, and for the four	93	12	0
To two overseers, at 40*l.* per year each, to take account of the time, and oversee to the works of the above men, supposed to be divided into two gangs	80	0	0
To a surveyor per annum, for directing the repairs of the whole	80	0	0
To workmen's wages	503	4	0
The tolls and materials consumed by the working hands, I suppose will be equivalent to their wages, the two first articles will therefore be	343	4	0
Expense of common annual repair	846	8	0
To the clerk for collecting the tolls from the toll-gatherers, and paying the same to the treasurer once a month, and keeping the accounts relative thereto, per annum	80	0	0
To two toll-gatherers, one at each end of the canal, at 40*l.* per year each	80	0	0
To one ditto at the point of partition	30	0	0
To six men stationed as lock-keepers on different parts of the canal to be a check upon the bargemen from doing damage to the works, by running against the lock-gates, leaving the clough running, so as to let off the water, &c., at 3*s.* 6*d.* per week	54	12	0
To books, paper, &c., per annum	15	0	0
To letters, messengers, and other contingent expenses	30	0	0
To clerks, toll-gatherers, lock-keepers, &c.	289	12	0
To common annual expenses	846	8	0
Common annual expense	1136	0	0
Supposed to be laid by every year, to answer the above, and for the purposes after mentioned	1600	0	0
Then the annual overplus will be	464	0	0
This, in 20 years, will amount to	9280	0	0
I suppose in 20 years' time many of the locks will want new gates, all which will gradually fail in a few years after, I, therefore, suppose them all made at the end of 20 years, and, therefore, 72 locks at 60*l.* per lock	4320	0	0
The bridges, and other works of timber, will likewise want repair, which I suppose, upon the whole, to amount to one-sixth of the locks	720	0	0
Sum of these repairs	5040	0	0
This, taken from the above accumulated sum of 9280*l.*, leaves in hand at the end of 20 years	4240	0	0
The interest of this sum for 20 years more, at 3 per cent	2544	0	0
The accumulation of the overplus sum of 464*l.*, will, in the second 20 years, amount to, as before	9280	0	0
Money in hand at the end of 40 years	16,064	0	0
The second set of lock-gates will, at the end of 20 years more, want renewing as before, and as the thresholds will want renewing also, I estimate the repairs at 70*l.* per lock; this for 72 locks, will be	5040	0	0
Carried over	5040	0	0

	£.	s.	d.
Brought over	5040	0	0
And as the second repair of other work may be in the same proportion, that is, one-sixth of the locks, this will be	840	0	0
Repairs wanted at the end of 40 years, which deduct from the above sum on hand	5880	0	0
Remains in hand at the end of 40 years	10,184	0	0
The interest of this sum, at 3 per cent, for 20 years	6110	8	0
The accumulation of the overplus sum of 464*l.*, will, in the third 20 years, amount to, as before	9280	0	0
Money in hand at the end of 60 years	25,574	8	0
At the end of 60 years I suppose the locks in general may need rebuilding, but as the greater part of the stone, and some other of the materials may be of service, and the excavation ready made, I suppose they may be as good as at first, for 300*l.* each; at an average, therefore, will cost	21,600	0	0
And if we suppose the other works to follow in the same proportion as before, they will cost, to make all good as at first	3600	0	0
To making all the works as good as at first, at the end of 60 years, which deduct from the money in hand	25,200	0	0
There remains an overplus in hand, at the end of 60 years, after every thing is made as good as at first	374	8	0

N.B. In the preceding estimate I have endeavoured to shew what sum of money applied from the beginning, will preserve the work to perpetuity; but I apprehend this to be altogether a needless supposition; for, if the work will defray the common expenses and repairs for the first 20 years, viz., 1136*l.* per annum, there is no doubt but that the increase of trade naturally following the use of these undertakings, will answer the greater repairs that must afterwards follow.

Austhorpe, December 22, 1764. J. SMEATON.

To the Honourable the Board of Trustees for Fisheries, Manufactures, and Improvements, in Scotland.

MINUTES CONCERNING FORTH AND CLYDE.

When Mr. Smeaton was applied to to survey the canal from Forth to Clyde, no estimate was given him of any quantity of tonnage that might be supposed yearly to pass from one Firth to the other; and being generally supposed, that the great difficulty would be to provide water for the necessary tonnage, the great object of his Report was to shew how large a tonnage of goods might be navigated with the water that was clearly and certainly producible; and that to work the largest size boats, that in his opinion, would be convenient for an artificial navigation: upon that proposition, he formed his estimate, observing, at the same time, "that if, in the execution, it should appear that the supply of water should turn out more liberal, or a less number of vessels be expected to navigate than he had supposed (that is, supposing a lesser tonnage to pass than computed upon), then some expense may be saved by making the locks greater in general (that is higher) and without preserving a strict equality." The highest lock determines the quantity of water to be used.

The quantity of tonnage that this canal was estimated to be capable of navigating in the driest seasons, was 208,000 tons a year; but the quantity expected, it seems,

is not above 25,000, which is short of one-eighth part of the quantity computed upon; so that hence, it appears, the locks may be of any height that convenience may suggest. I am very far from thinking that 25,000 will be the whole annual tonnage of the canal, if executed, to carry such vessels as I have proposed; but supposing four times as much, that is, 100,000 tons per year; then, by the same rules, the locks may, instead of 4 feet, be made 8 feet high, this would reduce their number to 36 instead of 72; and as an 8-foot lock may be built as well for 600*l.*, as a 4-foot lock can be built for 400*l.*, the whole expense in this article only will be reduced to 9200*l.*

It is mentioned in the Report, that the canal is proposed to be dug 1 foot deeper than the draught of water which the barges will draw, in order that the canal may be a reservoir within itself, to answer the exhalations in dry seasons; but, it appearing from the reduction of the supposition of tonnage, that there will be a great deal of water to spare, the extra depth on this account will be unnecessary, and as 6 inches beyond their draught of water is very sufficient to allow the vessels freedom of motion, the whole canal may be reduced 6 inches in depth, which will produce a saving of 1678*l.*, the article of widening the canal of partition, will also become unnecessary, amounting to 667*l.* Therefore, after adding 1322*l.* 10*s.* the sum by which the estimate is affected on account of an increase of length (see Postscript, page 308), and deducting the above articles, the estimate will then become 68,647*l.* 10*s.* 6*d.** to execute the plan first proposed, that is, to carry ga boats of 40 tons.

In order to come at the merits of the question, let us now see what reduction can be made by a supposition of using vessels 8 feet narrower, and drawing 6 inches less water than according to the former suppositions; and deducting the value of those savings, according to the former estimate, we shall have the true comparative value of the two plans; for to compare, according to the estimate of different persons, working from different dimensions and supposition of prices, can never be a true comparison at all; for whatever may be saved by working cheaper, is equally applicable to the plan proposed by Mr. Smeaton, as by the new proposed canal, and, therefore, leaves the difference nearly the same.

Supposing, then, the locks to be of the same height and number as above proposed, viz. 36 of 8 feet high each, the same in the smaller canal as in the larger (which is a supposition in favour of the small canal, as the multiplying of locks can never lessen the expense), as the walls of the smaller locks must be of the same height and thickness, and nearly of the same length, they must be of the same strength; there will, therefore, be nothing saved but in the width of the gates, the floor and the excavation; the whole of which, as nearly as I can judge, will be about 75*l.* per lock, which, for thirty-six, amounts to 2700*l.*

The width of the canal may, with propriety, be about 12 feet less for a 9½ feet boat than for a 17½ feet boat, and drawing 3 feet 6 inches water instead of 4 feet; it may be half a foot shallower: the difference of these dimensions will, at the same prices, produce a saving of 8076*l.* 10*s.*

The ground occupied will be less in breadth by 12 yards, which, upon the whole canal, at the same price per acre, saves 2918*l.* 10*s.*

The difference in the bridges, tunnels, and other extra articles, affected by a difference in width, I estimate at 1516*l.*

The sum total of these four articles of saving is 15,211*l.*; but as it may be supposed that the round sum of 10,000*l.* at the tail of my estimate, for contingent

* This sum is wrong, see page 309.

expenses, will be proportionably less upon a lesser work, the proportional reduction on this account will be 2594*l.*, which, with the saving before, amounts to 17,805*l.* difference between the two plans. They will then stand thus:

	£.	s.
To execute the greater canal to carry ga boats 17½ feet wide, and drawing 4 feet water, of 40 tons, as first proposed, having plenty of water	68,647	10
To execute the less canal for boats of 9½ feet wide, and 3 feet 6 inches draught of water	50,842	10
Difference.....	17,805	0

which is a saving of little more than one-quarter of the sum necessary for the greater canal.

But if, instead of reducing the depth of the greater canal 6 inches, we suppose the vessels to load down to 4 feet 6 inches, then as there will be no fear of wanting water, they will carry 12 tons more, and occasionally may draw 4 feet 9 inches, which will enable them to carry 18 tons more.

As I was unwilling to overrate any thing in my Report, I have called the tonnage of the vessel therein proposed 40 tons, but in reality they ought to carry at 4 feet draught of water 48 or, rather, 50 tons neat weight; but as the water-carriage is often lumped, and more than neat weight carried, that nothing might fall short in practice, I called them in round numbers 40 tons; reckoning, therefore, according to neat weight, 4 feet will carry 48 tons; 4 feet 6 inches, 60 tons; and 4 feet 9 inches, 66 tons.

By a like computation, a vessel 55 feet long, 9½ feet wide, and drawing 3 feet 6 inches water, may (lighter built) carry in smooth water, upon the canal only 33 tons neat weight; but if built so as to sail upon the Firths, cannot carry above 26½ tons: a vessel also of the same width and depth, but 36 feet long, may (lighter built), in the canal, carry 20½ tons, but built for the Firths, not above 16½ tons neat weight.

Supposing the canal to be of the depth originally computed upon, in order from the surplusage of water to take an advantage of a superior tonnage of vessels; the article of reduction arising from six inches depth of water, must then again be added; the account will stand thus:—

	£.	s.
To making a canal from Forth to Clyde, for vessels 17½ feet wide, drawing 4 feet 6 inches water; and navigating the Firths equally with the canals, and occasionally the coasts in summer, of fifty tons burden	70,335	10
To making a canal from Forth to Clyde, for vessels of 9½ feet wide, and drawing 3 feet 6 inches water; and navigating the Firths (I apprehend with much less safety, and the coasts not at all), of 26½ tons	50,842	10
Difference of expense	19,493	0

The merits of the two plans I leave to others to determine.

It is to be observed that the charge of carriage of goods does not depend upon the toll of the canal, but of that with freight, and other charges conjointly.

It now remains to explain a passage in my Report:

"I found that a middling ga boat of fifty-six feet length, stem and stern, 17½ wide, and drawing four feet water, will carry at least forty tons; and this I look upon to be the largest size that will be convenient for an artificial navigation."

I never meant by these words to limit the size of vessels, fit for any artificial navigation; nor do I in fact determine any thing; but my own opinion was, that this was as large a size as would be convenient for an artificial navigation so circumstanced in regard to water, trade, and prospects of funds to execute.

That this was the largest sized vessels that could be carried upon an artificial

navigation, would have been very absurd in me to say, having very frequently asserted the possibility in point of art, to carry first rate men-of-war across this tract; but in this scheme I paid more regard to what I thought was fit and likely to be carried into execution, than what was possible in itself; and this is not determined any way otherwise than as a matter of opinion at that time. So that if any body afterwards should be able to prove the expediency of larger vessels, I have no hesitation of the possibility of performance. As to the increase now mentioned, it is not a new thought; but what I saw as clearly at that time as now; and imagine every body (being nothing more than a deduction of common sense) would see as clearly as myself.

In fine, though after the lapse of nearly four years, my ideas may be presumed to be extended; yet I have no great reason to vary my opinion much on this point; for I conceive, that after having provided a passage for such vessels as can navigate both the Firths, very well and safely, and coast occasionally; that to extend the canal to such dimensions as to navigate vessels capable of going foreign voyages, would so greatly enhance the expense, that, considering the quantity of goods coming under this denomination only, the additional convenience betwixt going through and reloading, would no way answer the interest of the additional capital; and, if not, I consider it to be no matter whether the money goes from public or private hands; for, if the former, the sum had better be applied to cheapen those means that are naturally adapted to do the business the cheapest way. After all, this being a matter not within my profession as an engineer to determine, whenever the contrary is clearly evinced to the satisfaction of those whom it may concern, I readily submit.

ESTIMATE

Of the probable Expense of Executing a Canal through the Tract formerly proposed by Mr. SMEATON, from Carron Shore to Barns of Clyde, for Vessels drawing 8 *Feet Water,* 20 *Feet wide, and* 60 *Feet long, and upon a supposition that, at a medium, each Lockful of Water passes fifty Tons of Water from West to East, and twenty-five Tons from East to West, and to navigate at this rate* 100,000 *Tons per Year.*

	£
For vessels of 20 feet wide, I suppose the canal to be 27 feet botton, and 8½ deep of water, and at an average 10½ feet deep, within soil; this, with slopes, as in the former estimate, will make the width at top 62 feet; this, at 5*d.* a cube yard at an average, will come to 1906*l.* 13*s.* 4*d.* per mile, and for 28¼ miles	53,864
The width of the canal at top being 62 feet, and as the matter cannot be heaped up so high in proportion to the depth of the canal, as when it is shallower, instead of allowing twice the breadth for the canal for depositing the matter, I think it necessary to allow three times, so that the whole width over all will be 83 yards; this will contain 30 $\frac{2}{10}$ acres per mile, and for 28¼ miles 853 $\frac{8}{10}$ acres, which, if purchased at a medium of 20*l.* per acre, as before supposed, comes to	16,064
Supposing the vessels to have their bowsprits to turn up, or unship, then the locks need not be above 72 feet long, and, being 20½ feet wide, they will pass (in vessels at a medium capable of carrying fifty tons, as before mentioned), 100,000 tons annually, and the locks may be of eight feet rise; but being of greater depth and strength than before required, they will probably cost 1000*l.* each, and being thirty-six in number, will come to	36,000
The extra cutting, banking, bridges, tunnels, and other works, including contingencies in the former estimate, comes to 23,178*l.*, but for this work I estimate them at double, which will, therefore, be	46,356
	152,284

N.B. If small locks are made by the side of the former for lighters, they will cost about half as much as the great ones, that is, an addition of 18,000*l.*; and if the

vessels are made with fixed bowsprits, the locks must be made considerably longer, and will, therefore, cost more money, and navigate less shipping, unless the locks are also increased in number.

INSTRUCTIONS

For Mr. MACKELL, relative to the Proposed Canal from Forth to Clyde.

Mr. MACKELL is desired by Mr. SMEATON to examine afresh all the circumstances relative to the tract of the intended canal through Dolater bog, and of the resources for supplying the same with water; and, if the time will allow, to get the level formerly taken by Mr. SMEATON verified, also to examine the different tracts or passages whereby the canal proposed by Mr. SMEATON, to terminate in the Carron shore and barns of Clyde, may be extended to the Firth of Clyde into deeper water; and to examine the soundings of the two Firths, till every impediment is incontestably out of the way of all such vessels as are proposed to navigate upon the said canals. To examine the matter or soil of the fords or shallows where obstructions are likely to happen, and particularly such as lie below the mouth of Dalmoore burn, upon the Clyde, as also Erskin sands, and Dumbuck ford, with the length of space that each impediment contains.

Also, to examine wherever any difficulty shall appear likely to arise, in the practicability of cutting the ground, to the average of ten or eleven feet below the soil, whether from rock, bog, mud, or running sand, to ascertain the same by boring, or such method as may appear from circumstances the most proper in each particular case: also particularly to note the most proper tract for carrying the canal from Grascuddon to Dalmoore burn, how far the canal can be carried below the same, and what difference of depth of water can be obtained by such further extension, and, particularly, if the canal can be carried into Clyde below Erskin sands.

To examine likewise the tracts and levels of the grounds most proper for carrying off the branch canals to Glasgow and Barrowstoness, noting the length of base and section of such grounds as are likely to be above the level of the canal; and, also, the breadth and section of such hollows as must necessarily be filled up or banked, in order to support the canal across the same, with all such circumstances as appear to Mr. MACKELL proper to be inquired into, in order to ascertain the method of execution of the proposed scheme, and the true costs that may be likely to attend the same.

The above is desired to be done the first week in July, when, or as soon after as possible, Mr. SMEATON expects to be in the country, to examine the premises.

LONDON, 16th of May. J. SMEATON.

THE SECOND REPORT

Of JOHN SMEATON, *Engineer, and F.R.S. touching the Practicability and Expense of making a navigable Canal from the River Forth to the River Clyde, and thereby joining the East Sea to the West, for Vessels of greater Burden and Draught of Water than those which were the Subject of his first Report.*

HAVING, in my former Report, endeavoured to explain as clearly as possible the general situation of this tract of country, together with the principles upon which a work of this kind must proceed; having also explained my reasons for preferring the Carron Passage to that by way of Loch Lomond, and it further appearing to me, that every argument against the Loch Lomond Passage holds the stronger, as the size of the canal is supposed larger;—I shall now confine myself to the Carron Passage, and to such points as the difference of the present design and circumstances likely to attend the execution, make necessary to be more particularly explained or enlarged upon. Supposing, therefore, my former Report, signed the 1st of March, 1764, in the hands of every one concerned, I shall consider this as supplemental thereto.

I must here beg leave to observe, that in the forming of the scheme that was the subject of my former Report, I had no data to proceed upon, no estimate of quantity of tonnage, dimensions, or sorts of vessels proper to be used: my instructions from the honourable board of trustees, which were verbal, being, as I understood them, to give them a design for the sort of canal, that, in my judgment, would best suit the country, when taken in every point of view.

As I considered the making a canal across the kingdom from sea to sea (though here the most practicable of any place I had seen) as a work of very considerable expense; to have made a design upon so large a scale, as to have stood no chance of being executed, seemed to me in no respect fulfilling the general purport of my orders. I had therefore no idea of designing a canal for sea-built vessels, proper for going upon foreign voyages, no such canal having yet appeared in any part of the world, and this being, in a manner, the first attempt toward an artificial navigation by locks in Scotland.

My business, therefore, seemed to be to look out for the least sort of vessel that would safely navigate the two Firths, and occasionally go coastways. Of those I assigned the dimensions and tonnage, and those "I looked upon to be the largest size, that would be convenient for an artificial navigation," for to make larger vessels and works, without making them proper for sea vessels, seemed to me to be likely to be attended with additional expenses, to which the difference of utility would be no ways adequate. This way of reasoning produced the above expression of limitation, not any appearance of natural impracticability: but this matter having been taken up by gentlemen versed in trade, who are of opinion, that a passage for sea vessels would be of great public utility, and that sentiment being espoused by the principal noblemen and gentlemen of the country, it now becomes probable, that sufficient funds, which before seemed the principal obstacle, may be raised for the execution thereof.

The proposition therefore now stands thus:

To ascertain the practicability, general design, and expense of a canal capable of navigating vessels drawing eight feet water, and of such as are sixty feet long, or twenty feet wide, with a supply of water for the passage of 100,000 tons of mer-

chandise yearly, upon a supposition that two-thirds of the above quantity pass from west to east, and one-third from east to west, and that among different sorts of vessels, they carry, when loaded, fifty tons at a medium.

It is also proposed to carry off a branch to Glasgow of equal dimensions to the main canal, and to extend the canal at the west end as far down the river Clyde as Dalmoore's burn foot, at the least; also to extend it at the east end as far down as a place called the Hewk Farm, near the mouth of the river Carron.

I am also desired to consider what will be the difference of expense, in case the canal is made of seven feet, or of ten feet deep. These are the propositions or data upon which I am now to proceed.

As a necessary supply of water is the principal requisite, I shall begin with this point first.

If two-thirds of 100,000 tons of shipping pass one way, and the vessels return some loaded, some half loaded, and some empty, so as upon the whole to carry back half loads, or one-third of 100,000 tons, it will be the same thing in point of water, as if they carried two-thirds of 100,000 tons each way: now, two-thirds of 100,000 is 66,666⅔ tons, which, divided by fifty tons, the average quantity of each vessel, gives 1333⅓ for the number of trips made by the vessels altogether in a year; and as each vessel will take four locksfull of water for her passage backwards and forwards, that is, one at each end of the canal of partition going, and the same in returning with her half load, the number of locksfull expended yearly will be 5333⅓.

The tonnage and number of vessels being considerably less than what was stated in my former Report, the locks may be admitted of greater capacity, and perpendicular rise, as mentioned page 306, which will render the navigation more simple, and the stoppages less frequent. Supposing them now to be of eight feet rise each, to take in vessels of sixty feet long, and twenty feet wide, they should be seventy-two feet long, and 20½ feet wide, which locks will contain 11,808 cube feet of water to fill them, this, multiplied by 5333⅓, the number of locksfull in a year, gives the annual lockage of water equal to 62,976,000 cube feet, which, divided by 365, gives the expense per day, 172,482 cube feet.

If we allow the leakage per day equal to four locksfull, as per former Report, (page 300), then the leakage will be 47,232 cube feet per day.

With respect to exhalations, as the whole canal was before proposed to be dug one foot deeper than the draught of water proposed for the boats, and as also observed (page 300), the loss by exhalations does not exceed ten inches, the canal would have contained in itself a reservoir of supply thereof, but, as we now propose, in order to save expense in extra digging, to make every advantage of depth of water, the exhalations must be otherwise accounted for and compensated. When deep standing waters lose to the amount of ten inches perpendicular, it must be in a long drought of three or four months' continuance; now, if we suppose ten inches to be lost in 100 days, this will be at an average of one-tenth of an inch per day, which very well agrees with such observations as I have made since that time.

The whole extent of the canal will be about thirty-seven miles, and about 55½ feet wide at the water-line; but to take in passing places, turning places, and other extra widths, we will take the average width at sixty feet; the whole superficies then will be 11,721,600 feet, which, at one-tenth of an inch deep, will contain 97,680 cube feet for the mean daily evaporation.

The soakage is a matter that it is impossible to make any estimate of, as it depends upon circumstances that cannot be allowed for; and though in sandy and gravelly ground it will at first be considerable, yet experience shews that in a

moderate space of time, these soils, when fully saturated and wrecked up with the sediments of the water, become as tight as other soils; and as in the course of the canal many springs must be expected to be cut, which will afford a supply of water, it is probable that the loss by soakage after a year or two will be next to nothing.* Yet, that we may not be deceived, I will suppose the soakage equal to the exhalations, which I look upon to be an ample allowance, the account will then stand thus:

	Cube feet.
Water expended by lockage per day	172,482
by leakage	47,232
by exhalations	97,680
by soakage	97,680
Total expense of water per day	415,074

When I made my former report, it appeared, that the supply of water, even in the dryest seasons, was so superior to what was likely to be wanted for the locks then proposed, that I did not see it necessary to enter into the computations of some supplies that were but barely mentioned; but as we now want a supply of 415,000 cube feet water per day, instead of 152,000, as before set forth, page 300; and as the affair of water has been most in doubt, I shall endeavour to set forth this article more at large, and for this purpose, I have not only re-examined the supplies formerly mentioned, but shall bring some to account that I was not then informed of.

The burns or brooks that more immediately offer themselves for supplying the canal of partition, are the following:

1st. Achinclough burn. 2d. Wineford coal-pit drain, or level. 3d. Redburn. 4th. The Garron burn, which turns Kilsyth mills, and in my former Report, called Kilsyth burn. 5th. Culeam burn, not noticed before; this falling into Garron burn, some distance below the mill, forms the burn of Kilsyth. 6th. Shawend burn.

First. The Achinclough burn, in regard to discharge of water, I find, as before represented, viz. that is, to produce 89,343 cube feet per day, in the dryest seasons. Achinclough mill has indeed lost half its water by its being diverted to another mill; but as this mill's water falls into Dolater bog, the whole quantity reckoned upon Achinclough burn will remain the same.

2d. Wineford coal-pit drain is said to be constant the whole year; I gaged its water the 17th of August last, and it then amounted to 25,000 cube feet per day.

3d. Redburn has no mill upon it, so that it is not easy to say what its discharge may be in the driest times; in common it is as big as Achinclough, which led me to suppose it the same at others, but on my last view I was informed that in dry weather it is far less, yet always has running water, and never less than Wineford coal-pit drain.

N.B. Castle Cary mill takes in all the preceding, but its dam-head is so leaky that no conclusion can be formed therefrom in dry times.

4th. The Garron burn is set down in my former report at 87,003 cube feet in dry times, but, from information and measures taken on my last view, it comes out only 65,365. The miller last informed me that the late drought was one of the

* It is to be observed, on the article of soakage, that in soils subject thereto, those parts of the canal will be filled in rainy seasons, and kept supplied with muddy waters; so that it is to be reckoned upon that all the most considerable leakages will be stopped before the canal is opened for use.

greatest he ever knew, yet it continued only to affect them with a scarcity of water betwixt seven and eight weeks; and that in the driest part of this time they could work the mills three hours per day. From this the above computation is taken, whereas, in 1763, I was told this mill could go four hours, as in all ordinary dry times I suppose it can, which sufficiently accounts for the difference of the above results.

5th. Culeam burn was not before pointed out to me; it has no mill upon it, but all accounts agree that it is at least one-third of Garron burn at all times; it will be carried along with the Garron burn into Shawend burn.

6th. Shawend burn turns a lint mill near a place called Townhead, about a mile from Dolator bog: this mill is sometimes assisted by a part of the water of Culeam burn, sometimes not; but exclusive of any such assistance, they can, in the driest times, by the water of Shawend burn only, work two hours a-day, and if they get the whole of Culeam Burn, the miller supposes they could work four hours. Having gaged their water-ways, I find this mill in two hours will spend 27,432 cube feet, exclusive of a constant waste for want of tightness at the dam-head, &c.

Besides the above, by extending an aqueduct trench to the westward from the Kilsyth mills, a number of springs may be intercepted, which form small burns that now run down into the Kelvin; among the number of which are the West burn, Arnig, and Guine burn; and, by like means, on the eastward of Redburn, are Acre burn, Trannock burn, and several others.

Previously, however, to any computation, I must take notice, that if 100,000 tons of goods are to be navigated yearly, it is not necessary to suppose that the same proportion thereof is to pass in the driest time of the whole year as when water is plenty: there are very few navigations but what are sometimes scarce of water; if, therefore, a navigation be capable of carrying at the rate of 100,000 tons a year in the very driest times, it is capable of carrying a much greater quantity upon the whole, and that without sensible inconvenience.

I take it for granted, that generally the mills upon the burns have a full supply of water, so as to keep them going the whole twenty-four hours for full seven months in the year, and that they are supplied with water to work twelve hours in twenty-four for at least two months more: so that there will not be above three months in a year that they can be at short water, and probably much less than that at the extreme of scarcity.

Let us, therefore, examine, in the first place, what our supply will be when the mills are fully supplied with water, which takes in at least seven months in twelve:

	Cube Feet.
1st Achinclough burn	476,496
2d. Redburn in this state supposed equal	476,496
3d. The coal-pit level at Wineford	25,200
4th. The Garron burn which turns Kilsyth mill	370,388
5th. Culeam burn, being one-third of the former	123,463
6th. Shawend burn, in this state as good as Garron burn	370,000
The ordinary supply per day	1,842,043

Hence it appears, that in the ordinary state of the supply, the Achinclough burn alone is sufficient, and that they altogether afford as much water, in one day, as will last almost four and a half days, exclusive of the times of great rains and floods, when it is certain as much water may be collected in one day as will serve the canal fifty.

Secondly. When the burn affords as much water only as to turn the mills twelve hours in twenty-four, then the account will stand thus:

	Cube Feet.
1st. Achinclough burn	238,248
2d. Coal-pit level at Wineford	25,200
3d. Redburn, supposed now one-third of Achinclough	79,416
4th. The Garron burn	196,088
5th. Culeam burn, one-third of the above	65,363
6th. Shawend burn, equal to Culeam burn	65,363
Common supply in dry weather	669,678

Hence it appears, that, in common dry weather, the burns afford as much as is wanted for the supply of the canal, and more than half as much to spare, so that three days' water is then supplied in two.

Thirdly. We come now to extraordinary droughts:

	Cube Feet.
Achinclough burn, as per former Report	89,343
The Wineford coal-pit level	25,200
Redburn, then supposed the same	25,200
Garron burn, which turns Kilsyth mill	65,365
Culeam burn, one-third of the above	21,788
Shawend burn	27,432
Supply in great droughts	254,328
Computed expense of water per day	415,074
Deficiency per day during great droughts	160,746

It is to be remarked, that the above deficiency entirely arises from the allowance for exhalations and soakage, neither of which was necessary to be brought to account in the scheme; for, exclusive of these, there would be a redundancy of 34,614 cube feet per day. It is, however, to be noted, that when the mills have but about seven hours water in twenty-four, there will be a full supply for the canal, and that it seldom happens that any drought continues in that degree above seven or eight weeks. It must also be noted, that as the deficiency by exhalations and soakage gradually increases from the canal of partition toward the extremities, the supplies for this purpose are not necessary to be conducted to the canal of partition, but may be occasionally taken in by the way: and, therefore, that these deficiencies may be supplied by the several burns whose names have been mentioned, but not brought to account for supplying the canal of partition; yet I shall shew, that, independently of these burns, and others that may be brought in to the same purpose, the deficiencies above stated may be most certainly and amply supplied as follows:

It is mentioned, page 294, of the former Report, that Dolater bog may very easily be put under water by way of reservoir: on this occasion it has been measured, and found to contain upwards of 220 acres English measure. Respecting the twenty acres for other works, we will suppose 200 acres of Dolater bog, by a dam at each end, laid six feet under water; out of this, for supplying its own exhalations, we will allow one foot of perpendicular; we can, therefore, reckon, in time of need, to draw five feet of water from the Dolater reservoir, which will contain, at that depth, 43,560,000 cube feet, and, consequently, as much as will supply the aforesaid deficiencies for 270 days, or almost three quarters of a year, or would alone supply the whole quantity for 105 days!

Hence it appears that Dolater bog being turned into a reservoir, would, if necessary, supply the canal during the time of great drought, without taking any water

from the burns; or with their assistance as above, would navigate more than double the quantity of goods required even in the driest seasons.

Nor yet are those the only resources that could be procured if occasion required. In the reservior way, it is remarkable that the whole face of the country, abounding in hollows, affords frequent opportunities for making them; in particular, a dam not above fifty yards long, where the dam-head of Townhead lint-mill is now fixed, would lay a valley under water four or five fathoms deep, and thereby form a reservoir equal in capacity to that of Dolater, already proposed.

This reservoir would not only be supplied by Shawend Burn, which takes its course through it (and which, though small in dry times, seems to be the best of them all, for supplying reservoirs by downfalls of rain) but will also receive the waters of Garron burn, Culeam burn, and Achinclough, all of which may be diverted thereto. The waters of Bishop's Loch and four others in the same neighbourhood, forming altogether a surface of between three and four hundred acres, and which might be pent up from four to six feet higher than at present, may also be brought to Dolater bog. But, without insisting further on reservoirs, many more yet of living waters may be applied to our purpose by bringing them from a somewhat greater, though no remarkable distance; in particular, on the south side of the canal, the Loggie water may be intercepted and turned to Dolater bog, from a point where it is as considerable, if not more so, than any of the burns mentioned. On the north side the water of Glazert, a considerable rivulet, and along with it all the burns west of Kilsyth, viz. West burn, Arnig, and Guine burn, before mentioned, may be brought so as to fall in with Garron burn and Culeam burn into Shawend burn, and then proceed altogether into the Dolater bog. Furthermore, into the head of the Glazert, may not only be turned the water from the spout of Ballagin, and a great number of springs that feed the head of the water of Blain, but even a great part of the river Enrick (I believe quite as much of it as can be carried to the bog of Bollat), may be brought round the hills upon a sufficient elevation to fall into the head of the Glazert, and be therewith carried to the point of partition: in short, were ten times as much water necessary for the canal as what appears to be, there are the evident means of bringing it, and amassing it without making any strain upon nature: I, therefore, beg leave once more to repeat a passage of my former Report, page 301: "it does not admit of a doubt but that nature has furnished a practicability of bringing as much water to the point of partition as can possibly be wanted, and that by means sufficiently simple and easy," and again, "so that there is all possible certainty that the canal will be amply supplied from end to end."

As the Glasgow branch will afford the means of navigating from Glasgow to Port Glasgow, and back again, in neap tides and dry seasons, it will undoubtedly be made use of for that purpose when the river Clyde will not serve; there will therefore be water expended by lockage in this passage of vessels not navigating from sea to sea; but as the branch canal to Glasgow is proposed to be carried on upon a dead level, and without communication with the river Clyde at its upper end, only one lockfull will be expended on the passage of each vessel into or from the Clyde.

I am in no condition to judge what quantity of water for lockage may be wanted in this branch of trade; but if as much water were to be used in this branch as will be used in passing from sea to sea, which will navigate four times as many goods upon the branch up and down as upon the transverse passage from sea to sea, there are so many rivers which fall in below the level of the canal of partition, and yet sufficiently above the level of the branch canal, as are sufficient to supply it ten fold, without letting down any water from the canal of partition at all on this account.

In like manner it is to be supposed, that at the Carron end of the canal many cargoes of goods will pass backwards and forwards without crossing from sea to sea, all of which will consume a lockfull of water each at their entry and departure from the canal, and yet more if a branch be carried off to Carron shore, as it easily may; but were this trade also equal to the trade across, there are likewise the means of supplying it with water, without letting any down from the canal of partition.

Having now shewn that there is a practicability of producing a most ample supply of water, not only to answer the greatest possible exigencies of trade, but also the greatest possible errors that may be made in computation, it now remains again to shew that we are in equal capacity of repaying the water that shall be necessary to be taken from the rivers that now supply the valuable iron works, &c. upon the Carron, and the valuable mills and iron works that are towards the foot of the Kelvin.

Here I must observe, that though I have shewn how it is possible to bring a vast abundance of water to supply this navigation, yet I have equally shewn how small a quantity really will supply it. It is sufficient, therefore, to repay to the full what we really are obliged to take.

Suppose, therefore, the navigation is supplied as first proposed, viz. by the six burns and a reservoir upon Dolater bog; it is manifest that we take nothing from the mills but the value of the six burns, in the dry seasons; for in all others, they are sufficiently supplied without them.

From what has before been stated, it appears, that 415,000 cube feet of water may be expected to supply the canal per day, but that from this what is allowed for soakage, viz. 97,000, ought to be deducted; because, as the soakage returns into the rivers, and will be maintained by means of the reservoir as great in the dryest times as in ordinary, they will get an over proportion when most wanted, and, therefore, be rather benefitted than hurt by this article: yet, not to be niggardly of a little water, nor to insist upon nice disquisitions where there is no necessity; for the present, we will allow that we are to repay 415,000 cube feet of water whenever the burns will furnish it, and in the dryest seasons whatever they do furnish, which at the least, we suppose to be 254,000. Now this is scarcely three times as much as the Achinclough burn yields in the dryest season singly; a burn, therefore, capable of running three times as much as Achinclough in the dryest seasons, and at other times in proportion, will afford as much water as will repay all the mills both on Carron and Kelvin; and as somewhat about half that quantity is due to one set, and half to the other, it will follow that a burn half as big again as Achinclough will repay the Carron mills, and another of the same size will repay those of Kelvin.

I have mentioned in the former Report, page 302, that the river Enrick, at Randeford, may be easily diverted into the Carron, and that it appeared to be there more than double of Achinclough: this I thought sufficient to make good my argument; but had I said four times as big, I believe I should have been nearer the mark: the burn of Ganakin I then but rarely mentioned, but it appeared to be near its fall into Enrick, full as big as the Enrick at Randeford, and having its rise in the Campsie Fells, it cannot be reckoned less than Achinclough at the level at which it may be diverted; hence we cannot reckon these burns together, at less than three times the estimated quantity of water necessary to be repaid to Carron, and, therefore, by half more than sufficient for the whole re-payment of vessels not passing from sea to sea; and will include the lockage at the Carron end of vessels not passing from sea to sea, were that supposed equal to the lockage of those that are; for it is to be remarked, that let the lockage be increased in whatever degree, the other articles of leakage, exhalations, and soakage, which make two-fifths of the

whole stated quantity, will still remain the same, and therefore it is extra lockage only that is to be provided for on these extra accounts; yet to this purpose of extra lockage at the east end (if we could possibly suppose it needed) not only the Grange burn, but a considerable part of the river Avon, could be brought round to supply the canal; and if this be not enough, as we have already said, the Loggie, the Glazert, the head of the Blain, and even the Enrick, can be brought round to the canal of partition, when their overplus waters may be sent down the rivers either way.

With respect to the repayment of the Kelvin mills, I am of opinion that the waters that can be turned into the Glazert from the spout of Ballagin and head of the Blain, will of themselves be found sufficient: but not altogether depending on this, it turns out from computation, that as much water can be accumulated it Bishop's Loch, and the four others in that neighbourhood, by penning them to the depth of three feet nine inches only, as is equal to the proposed reservoir of Dolater, and, consequently, will of themselves repay the Kelvin's proportion of supply to the canal of partition for 210 days or seven months, which is two months more that it ever happens that any of the mills can be the worse on account of the supply taken for the navigation.

Besides the above, the following is a list of such lochs as might, in like manner, be made use of for treasuring up water, which can be brought into the Kelvin in order to repay the mills, or supply the lower part of the canal on the west side, viz.

Loch Umphrey,*	320 acres, at twelve feet deep,	$1\frac{6}{10}$	}	times as much as the revervoir of Dolater.
Cockney Loch	80			
Ditto, as may be made by a dam	640 at twenty-four feet	15		
Bardoure Loch	82 at three feet	$\frac{1}{4}$		
Auchen Loch	80			
Postel Lock	80			

Also, a very large hollow in Kilmannan Moor, the land being of small value, that may be converted into a loch, and turned down the Allander.

Also, several small lochs, such as Kilmardonie Loch, Loch Green, St. German's Loch, and others.

Over and above all, we have the river Enrick for our sheet anchor, which, being taken up, as already observed, at a sufficient elevation to go over the low flat ground at the point of partition, between the Blain and the Glazert, is, of itself, sufficient to repay all that is taken for furnishing the navigation; that is, in other words, that the whole navigation might be furnished with water from the Enrick, without taking any thing from any burn or rivulet that at present feeds either Carron or Kelvin; indeed, this would have been the primary proposition, had not the thing been feasible by more direct and shorter methods; I therefore only mention those things to shew, that in case of any unforeseen occurrence or emergence, we are by no means limited to the supply of the six burns, or unable, in the nature of things, to repay any quantity that it may be needful to take.

It, perhaps, may seem that I have reckoned the Enrick twice, nay, three times over; first, in making use of it for a supply to the navigation; 2dly, in repaying the water borrowed from the Carron; and, 3dly, in repaying the water borrowed from the Kelvin.

But, in answer, I must observe, that if the Enrick be made use of as an immediate supply, it must be brought to the canal of partition; if that be done, it will be of

* This is what it may be made to hold, more than what it now does as a reservoir to Dalmoore mill.

itself a sufficient supply, and, consequently, there will be nothing to repay. If made use of to repay, it will do it to both without interfering; for the water of Enrick will be brought off so much lower down than Randeford, from whence the water is to be taken to Carron, when it has received several considerable rivulets and burns, that there will not only be water to repay what is due to the Kelvin, but water enough left for the mills, if properly applied, and, after all, water to supply another canal by the bog of Bollat, in case that also should be undertaken. But though it may be necessary to shew from what abundance of sources water may be drawn for the supply of the canal, yet I do not apprehend it will be necessary to disturb the Enrick at all, except at Randeford, as first proposed. And I am so thoroughly satisfied that there is upon the whole so much more water to be procured, than is sufficient for all purposes, that I cannot hesitate to declare, that the promoters of this undertaking may, for the satisfaction of the country, very safely oblige themselves not to take any water that falls into the heads of Carron or Kelvin in times of scarcity, but what they do actually repay in equal quantity at the same time to the lower parts of the same river.

It may, perhaps, be doubted, whether there are any certain means of knowing when two streams are equal, so that the parties interested may be satisfied that they have their just equivalent: for the satisfaction of those, it is incumbent on me to say, that water-gages both may and ought to be fixed, so that any person by inspection shall be able to judge at any time of the equality thereof; furthermore, as all overflowings will fall into the rivers, and as the navigation will seldom be able to use all the waters allotted to it, the Carron and Kelvin rivers will of consequence be gainers by this overplus.

The next great point is the places of entry of the canal from the rivers Forth and Clyde, and in this affair it is not to be doubted, but that the greater the depth of water where the entries are, *cæteris paribus*, they are the better.

Conveniences of trade are matters that I never undertake to judge of. I am, therefore, happy that the places of entry have been pointed out by a committee of gentlemen appointed to make due inquiries thereupon; whose opinion, after having been reported before the convention of royal boroughs, has been by them approved, viz., "That the most proper place for the entry from the Firth of Forth will be somewhere near the mouth of Carron, and on such part of the north-east side of a farm called the Hewk, as Mr. SMEATON may think proper, after a due consideration."

Now, having maturely considered this matter, I cannot hesitate to say, that the most eligible place for the entry on the north-east side of that farm, is that part which points down the sea reach whose general bearing is N.E. by E.: this entry is on many accounts a very proper one; for below this, there is no impediment in going out to sea, save a flat or bar just within the channel of the Carron's mouth at low water; upon which I found 5 feet water at low-water, the 14th day of August last, being the 4th day after the full moon, within which there is a deep called Holemerrie, extending nearly a quarter of a mile, and reaching almost to the place where the entry is proposed; this deep has 7 feet more water than the bar, and is, therefore, a very proper place for vessels to lie in when waiting for the tide.

It is to be observed, that the tide preceding, and that subsequent to the low-water, when I sounded, were the highest of that spring, which was a very moderate one, but which rose above the said low-water full 18 feet; so that there would be at least 23 feet water upon the bar or flat. The spring tides are said sometimes to make 27 feet upon the bar, sometimes to fall short to 21 or 22; the neaps make 18 or 19 feet upon the bar, and leave them about 9 feet at low-water; hence it appears, that

vessels drawing 8 feet water may go in and out at all times of tide in neaps, and that at low-water at spring tides, they may lie afloat in Holemerrie, till the tide serves, and that vessels drawing 4 feet water, such as formerly proposed, may go in and out at all times, except at the low-water of a very low spring ebb. These are certainly great advantages, but, on the other hand, as there is not sufficient shelter at high-water for such vessels as come here to deliver their cargoes, and which are too large to pass the canal, and as I do not apprehend it would be practicable for such vessels as intend to enter the canal to do it with safety when the wind is northerly, and blows hard; it will, therefore, in this case, be necessary either to dig an artificial harbour within land, or to make use of the turn of the river round the Hewk point, and the reach within the same, as a natural harbour, as now it is: the former will be attended with very considerable expenses, and not without inconveniences; the latter would be attended with the following:—

First. The bottom of the river in the Hewk reach, that is above or up the channel from the proposed place of entry, particularly at a place called the Hewk ford, is $3\frac{1}{2}$ feet higher than the bar; in consequence, in all cases, vessels will have $3\frac{1}{2}$ feet less water in going into the natural harbour than in coming over the bar; but as there is here no scarcity of water at high-water, this consideration, if alone, would be of less consequence. But what seems more material is, that when the wind blows at S.W. or W. which in those climates are the most general of all winds, vessels may and frequently do lose a tide in getting round the Hewk point; on the other hand, when in, an entry from about the Grange burn foot would at all times be safe, and with about 4 feet extra flow of tide, certain. In order, therefore, to take every advantage of the situation, I would recommend it to consideration, whether it would not be advisable to give the canal a double entry; one from the place already proposed, the other from the Grange foot; by this means the cost of a new artificial harbour would be avoided; and all vessels intended for the canal will, at all times, be sure of a safe entry; for such winds as will render the outward mouth difficult, will carry them to the inner mouth; which latter will, at all times, be accessible to goods and vessels from the material harbour.

The extra expense of the canal and interior lock, as well as some addition of leakage, will be objections; but as to the first, the cost will be very far short of making an artificial harbour; and, after what I have said upon the article of supplies, I flatter myself that the latter will totally vanish.

With respect to the west end of the canal, it is certainly very rightly determined by the committee "that the entry of the canal should not be higher up the Clyde than Dalmoore burn foot," for higher than this there is no certainty of water for vessels of any greater draft than those specified in my former Report; and even to Dalmoore burn foot, there is not that plenty of water that could be wished. Having carefully sounded the Clyde from Dumbarton to the Barns of Clyde, upon the 21st day of August last, being the 5th day after the quadrature, there was, at high-water upon Dumbuck ford, $7\frac{1}{2}$ feet, and over Erskine sands, above 8 feet; all other places betwixt deep water and Dalmoore burn foot sounded above 8 feet 6 inches and 9 feet. This tide somewhat exceeded the dead of neap, being the first tide that lifted; but as the ordinary neap-tides are reckoned at 7 feet 6 inches upon Dumbuck, and but 2 feet more at ordinary spring tides, and as the high-water mark at Dumbarton this tide fell short of the ordinary high-water of a spring-tide by 1 foot $10\frac{1}{2}$ inches; it is very certain, that it could have lifted not above 2 or 3 inches at most above the dead of neap; and as I look upon it very practicable to deepen Dumbuck ford 1 foot, or even $1\frac{1}{2}$ foot, and by contracting the low-water channel of the river, opposite

Erskin-house, by proper weirs to run down the loose sands of which it is composed, and constantly maintain at least as good a channel as at Dumbuck, it follows that vessels drawing full 8 feet water may, in moderate weather, and at high-water, in all ordinary neap tides be able to enter the canal at the foot of Dalmoore burn. The day when the above soundings were taken was remarkably calm and serene, so that it was probable it was unaffected by any winds; and, indeed, the near coincidence of our soundings, with the common estimation of those that use the river, proves it. It must, however, be observed, that the tides of this river are very liable to be altered by the winds, which frequently make them exceed, or fall short, 1 foot of the ordinary quantity. In these cases, it is possible that vessels drawing 8 feet water, coming at dead of neaps, and the wind in an unfavourable quarter, may have to wait a tide or two; but as S.W. winds make great tides, which are those which oftenest blow, we may reckon those stoppages to happen but seldom, and they may be placed among the unavoidable chances of navigation dependent on winds, which all vessels out of canals or narrow rivers must be subject to.

It were much to be wished, that the canal could as easily be extended to deep water below Dumbuck ford, as it can at the east end; but having maturely considered this matter as desired by the said committee, though I do not doubt of its practicability, if expense be unlimited, yet, considering how much more easily the river may be helped in the degree before mentioned, which seems to me likely to answer the purpose, I cannot recommend this part of the work to be undertaken for vessels of 8 feet water, but for vessels drawing $9\frac{1}{2}$ feet water, it will be absolutely necessary, and of which I shall, in the estimate, give the best account I am able.

The proper method of effecting it seems to be, to avoid the sleechy bottom, and whinstone rock, by making a strong sea bank within high-water mark, and to build a wall where the shore is rocky, so as to confine a body of water for the navigation of vessels between that and the main land; but at Dunglass the neck of whin rock between the castle and main land must be cut through, so as to afford a navigable passage.

In regard to the general course of the canal, the ground has been carefully examined by boring, by Mr. Mackell, whose abilities in engineery is well known, and who has delivered to me an account of the qualities of the soil for 12 feet deep, in no less than 58 different divisions; together with many other measures of the hills and hollows through which it has been designed to pass; also, remarks upon the great number of lochs that can be made use of as a supply, or for repayment of others which are so made use of; and to whose care and industry this business is much indebted. Having, along with him, carefully reviewed the course of the canal formerly traced out, it does not appear, that any very material alterations or deviations from that course are necessary, till we arrive at those places where we must turn off on account of the extensions. In regard to that at the east end, I find it advisable to bring the canal as before, to or near Bainsford (just beneath the word Camelton, in fig. 2, plate 37), where it intersects the road from Falkirk to Carron: in its passage from thence to the Hewk, it may be carried on either side of Kerse-house, the north side is the more direct, according to the dotted line P upon the plan: but as it measures but a quarter of a mile more, to go upon the south side, by Mr. Longmuir's house, and without interfering with the policy, I have made the design and estimate upon that footing, the difference of expense for the $8\frac{1}{2}$-feet canal being 558*l.*

The most material deviation that I have made from the former design, is by taking the Allander passage in preference to the Canny's burn. Having originally given preference to the Allander passage; that part of the tract of the canal from

the Allander to Garscud Bridge, was not surveyed, but was laid down by the eye; this alteration of my first intention, was what occasioned the want of an actual survey of that part; for finding, on computation from my notes, after I had left the country, that the expense of cutting the hill from Canny's burn into St. German's Loch, would be greatly short of cutting that by the Allander; this occasioned a correspondent alteration in my design. But upon this last review I find it will be necessary, in passing from the Allander to Canny's burn, to pass through two other hills as troublesome as the former. This would not have been necessary for vessels of the size I first computed upon: because, at all events, I knew I could conduct them down the course of the Kelvin itself to Garscud bridge; but this, for vessels of the size proposed, would be more troublesome to do than even the impediment we mean to avoid. As, therefore, upon the footing of the present scheme, it will not, according to the best estimate I can make, cost above 1000*l.* more to go by the Allander, than by the Canny's burn passage, and at the same time shorten the distance one quarter of a mile, as well as avoid the policy of Killarmine-house, with a less chance of unforeseen difficulties; on these considerations, I have now drawn and estimated the course of the canal by the Allander passage, at the same time stating the difference, in case the chance of the above saving is thought worthy of attempting.

The next considerable deviation is in order to avoid going through the policy of Grascuddon, by cutting through a rise of about eighteen feet extra height, which passage was pointed out by Mr. Mackell. This work I estimate to cost 238*l.*, which, with some lesser inequalities, may possibly amount to 300*l.* This will, indeed, throw the general course of the canal about three furlongs further round; but, as it will shorten the Glasgow communication by two furlongs, there is, upon the whole, only one furlong extra, the charge of which, for the 8½ feet canal, will be also about 300*l.* more; but, as this will avoid at least 300*l.* extra charge in passing through the piece of water at Grascuddon, and furthermore avoid the difficulties that may attend a muddy bottom, in going down from the point of deviation to Grascuddon, perhaps, upon the whole, there will be little difference in point of expense. I have, therefore, made the design and estimate according to this deviation.

Upon entering into the detail of this affair in the execution, it must be expected that many deviations may appear eligible; it is, therefore, not to be expected the canal can, at present, be fixed to a point, and I can only say in answer to those that might desire it, that I cannot take upon me to do it, and I think it would be very unadvised in any man so to do, even in works of much less bulk, extent, and expense than this. There must be a degree of latitude in an affair of such great consequence, for second thoughts and improvements,

Austhorpe, 8th October, 1767. J. SMEATON.

FIRST ESTIMATE

For a Canal from Forth to Clyde, for Vessels drawing eight Feet Water, and the Locks, &c. to contain those of twenty Feet wide and sixty Feet long, with a Branch of the same Size to Glasgow.

The canal, for vessels of twenty feet wide, and drawing eight feet water; if made of full width, so as to draw easy, should have a twenty-seven feet bottom, and be 8½ feet depth of water, which will require the canal to be 10½ feet deep at an average; this made with slopes at a medium as three to five, will, at 5*d.* per yard cubic, come to 1903*l.* 12*s.* 2¼*d.*

per mile; but, for even numbers, say 1904*l.* per mile, and the canal, including the Glasgow branch, with its extensions, as per plan, being thirty-seven miles, in the whole, will come to	70,448
This canal will admit of sea-built vessels, of the above dimensions, to pass in every part; but yet to allow for turning places and other extra widths, allow upon the whole one mile extra	1,904
The width of the canal at top being sixty-two feet, and the same width being allowed on each side for depositing the earth, and for back-drains, fore-shores, &c. the whole width will be sixty-two yards, which takes $16\frac{3}{10}$ acres per mile, and, for thirty-seven miles, 603 acres, which, if purchased at a medium at 20*l.*, will come to	12,062
Besides what is immediately occupied by the canal, it will be necessary to allow for aqueducts, trenches, reservoirs, and other conveniences, the value of 100 acres more, which, at the mean price of 20*l.* per acre, is meant to include Dolater bog	2,000
The perpendicular height before ascertained, from neap tide high-water mark to the surface of Dolater bog, is 147 feet; but, according to the present scheme, it will not be necessary to enter from the level of the bar, which is reckoned nineteen feet below high-water mark of neap tides; and as it may be advisable to keep the canal of partition two feet above the level of the surface of the bog, the whole perpendicular will be 168 feet, which at eight feet each lock, makes twenty-one locks upwards, and the same downwards, and will in the whole be forty-two locks; which, for vessels of the dimensions specified, ought to be $20\frac{1}{2}$ feet wide, and seventy-two feet long, which will cost 1000*l.* each	42,000
To an extra double lock, for a double entry at Grange burn foot, with extra expenses in diverting the burn	2,000
To making an aqueduct bridge over the Grange burn	500
To extra digging in passing a narrow gripe, between two rising grounds, west of Mungull's house	100
To extra digging through the summit of the ground, between Glenfour and Newhall, above Camelton	115
Extra banking across the hollows betwixt Newhall and Bonnie mill, and one small river	600
To an aqueduct bridge in passing Bonnie mill burn	1,500
To extra work in passing Seabegs wood, Trannock burn, Acre burn, and some other hollows, and rises from thence to Castle Cary bridge	400
To an aqueduct bridge for passing the river Bonnie, near Castle Cary bridge, and banking there	1,200
To extra cutting in the canal of partition, so as to make it a fifty feet bottom	1,478
To making two dams, one at each end of Dolater bog, so as to form the whole into a reservoir	300
To defending the dam heads and banks of the reservoir with stones against the wash of the waves	1,408
To making a sluice for drawing the water from the reservoir into the canal of partition, and over-falls for discharging the water each way	100
To building a dam and other works at Inch Belly bridge, for the passage of the canal there	500
To extra expenses in passing the Loggie at Kirkintulloch	300
To a dam and works at Calder bridge	500
To extra expenses in cutting the hill near New Kilpatrick, in the Allander passage, computed to be thirty-six feet above the bottom of the canal, the digging at 6*d.*, and walling at 5*s.* per cube yard	9,166
To extra expenses in cutting the hill by the weaver's house, above Grascuddon 238*l.*, this, with some other inequalities, may be called	300
To extra work in making a jetty to defend the mouth of the canal, from the lodgment of sand and mud, and clearing a passage into Clyde	150
To extra cutting in passing the rising ground opposite Blart hill, and in altering the turnpike road, upon the Glasgow branch	700
To building an aqueduct bridge over the river Kelvin, in order to carry the canal to Glasgow, including other extra expenses in passing that river	4,000
To making aqueducts, trenches, with such tunnels and bridges as may be wanted, for bringing the several supplies proposed into the Dolater reservoir	500
To six public roads, draw or turning bridges, viz. at the road from Falkirk to Carron and Stirling, Camelton, Inch Belly, Calder, and Brick-house, upon the road from Glasgow to Dumbarton, and one upon the branch canal, where the same road intersects it near Blart hill, at 600*l.* each	3,600
Carried forward	157,831

	£
Brought over	157,831
To ten draw or turning bridges of lesser dimensions, where the lesser roads intersect the canal, at 400*l.*	4,000
To twenty-one carriage bridges, of the draw or turning kind, for communications between the lands, which, with the great and small bridges, make at the rate of one in a mile, at 250*l.*	5,250
To fifteen large tunnels, for communicating the lesser brooks under the canal, at 60*l.* each	900
To fifty-nine small tunnels, for preserving the present watercourses, making, with the large ones, at the rate of two in a mile, at 20*l.* each	1,180
To making towing paths, back drains, gates, towing bridges, &c. at 25*l.* per mile	925
To bringing the water of Enrick from a little above Randeford into Carron	150
To bringing the burn of Ballagin, with some springs rising out of the hills to the west of the spout of Ballagin, that now fall into the water of Blain into Kelvin	100
To making trenches, sluices, &c. for drawing off the water of Bishop's loch, and three others in that neighbourhood, in case it shall be required	100
To expenses in making weirs to contract the channel at low-water for deepening Erskin sand	1,000
To deepening Dumbuck ford, so as to make eight feet six inches water at common neap tides	1,000
To temporary damages, unforeseen accidents, impediments, and works, engines, utensils, and surveyors' salaries, supposed at 15*l.* per cent.	25,865
	198,301

N.B. The above is exclusive of all expenses in making harbours, warehouses, quays, and other conveniences in landing, depositing, and shipping of goods, and of all expenses attending getting an act of parliament, and of all surveys, &c. previous thereto; and for all allowance of interest of monies, and of salaries to the principal engineers and accountants. Nor would I be understood to ascertain any thing as to the value of the lands, the number of acres excepted.

N.B. Whatever waters may be wanted further than the expense above computed will bring, must be in consequence of such an addition of trade as will very well pay all additional charges.

SECOND ESTIMATE

Of the probable Expense of making a Canal, of 10 *Feet depth of Water, from the Hewk Farm, at the Mouth of Carron upon the Forth, to below Dumbuck Ford, upon the River Clyde, with a Branch of the same size to Glasgow.*

The width of the vessels being 20 feet, as before, the same width of bottom will serve, viz. 27 feet, and the depth of water being 10 feet, we may call the whole depth 12 feet, the slopes being 3 to 5, as before, will, at 6*d.* per yard cubic, come to 2757*l.* 6*s.* 6*d.* which, for even numbers, call 2758*l.*, this, for 37 miles, will come to	102,046
According to the above dimensions, the mean breadth of the canal at top will be 67 feet, and allowing the same breadth on each side, for the banks, back-drains, and fore-shores, the whole breadth will be 67 yards, this will contain 19$\frac{4}{10}$ acres, Scotch measure, per mile, which, if purchased at a medium at 20*l.* an acre, comes to	14,356
The length, breadth, and rises at the locks, being the same as before, they will be deeper by 18 inches; which, together with a greater degree of strength necessary, not only on that account, but on account of the greater weight of vessels running against them, will produce a difference of at least 100*l.* in each lock; there will, therefore, be 42 locks, at 1100*l.* each	46,200
	162,602

In the foregoing estimate, for 8½ feet water, the whole cost is		£198,301
Deduct, viz. Cutting	£70,448	
Land	12,062	
Locks	42,000	
Fifteen per cent.	25,865	
Total deduct		150,375
Remains for extra works, lands, &c.		47,926
To this add one-third for increase in these articles		15,975
The sums will be the supposed expense of the same articles upon the increased plan		63,901
From the Forth to Dalmoore burn foot		226,503

THE ESTIMATE

For carrying the Canal from Dalmoore Burn Foot, to below Dumbuck Ford, being Four Miles, is as follows.

	£
To making an aqueduct bridge over Dalmoore burn	667
To making the canal within land ¾ of a mile below the foot of Dalmoore burn; that is, cutting and land, at the price mentioned of the first and second article	2,369
To raising a strong bank within the tide's marks, and thereby enclosing a space to be used as a canal; this, at sixpence per yard, is 3300*l.* per mile, and for 1 mile and ¾	5,775
To defending the same towards the Clyde, with stones; these at two shillings per ton, come to 704*l.* per mile, and for 1 mile and ¾	1,232
To building an aisler wall, where the whinstone rock interferes, upon a sloping shore, being about ½ a mile in length; the solid being computed at five shillings per cube yard, will come to	1,173
To aisler facing for ditto, at 8*d.* per yard	1,320
To forming a slope of earth within the same, at 6*d.* per yard, cubic	352
To cutting the neck of whinstone rock, behind the castle of Dunglass, so as to make a passage 24 feet wide, containing 64,000 cube yards, at 5*s.*	1,600
To 1 mile of cut below Dunglass, in order to clear the ford, and get into deep water; the cutting and land as per first and second article	3,146
This being done in the tide's way, we may add for drainage of water, and other extra expenses	400
From Dalmoore burn foot, to below Dumbuck head	18,034
From the Forth to Dalmoore burn foot	226,503
The whole work being attended with greater hazard of rocks, mud, and many other difficulties, I think it necessary to allow 20 per cent for contingent expenses upon the whole estimate	48,907
N.B. Exceptions as before	£293,444

THIRD ESTIMATE

Of the Expense of a Canal of 7 Feet depth of Water, from the Hewk Farm, at the Mouth of Carron to the Foot of Dalmoore Burn, upon the Clyde, with a branch of the same dimensions, to Glasgow.

As I suppose a canal of 7 feet deep, vessels of about 18 feet will be the ordinary size, a 24 feet bottom will be sufficient, and the mean depth being supposed 9 feet, this, with battens or slopes in the proportion of 3 to 5 at a medium, will, at 4*d.* per yard, cubic, come to 1144*l.* per mile, and this, for 37 miles, including the Glasgow branch and all extensions as per plan, comes to	42,328
Carried forward	42,328

Brought over	42,328
To allow for passing places, turning places, &c. I allow the value of 1 mile extra	1,144
The width of the canal at top being 54 feet, and the same width being allowed on each side for depositing the earth, back drains, fore shores, and other occasions, this will make a breadth of 54 yards, which is $15\frac{6}{10}$ Scots acres per mile, and for 37 miles, $577\frac{2}{10}$ acres, which, supposing the purchase made at a medium price of 20*l.*, will come to	11,544
Besides what is immediately occupied by the canal, it will be necessary to allow for aqueducts, trenches, reservoirs, and other conveniences, the value of 100*l.* acres more, which at the mean price of 20*l.* per acre, is meant to include Dolater bog	2,000
The perpendicular height of 147 feet, before ascertained from neap tide high-water mark, to the surface of Dolater Bog, must be added according to the present scheme, the height of the said neap tide high-water, above the level of the bar, viz. 19 feet. And as it may be advisable to keep the water in the canal of partition two feet above the level of the surface of the bog, the whole perpendicular will now become 168 feet, which, at 8 feet each lock, makes 21 locks upwards, and the same downwards, that is, in the whole 42 locks, which, if made $20\frac{1}{2}$ feet wide, and 72 feet long, to hold vessels of 20 feet wide, and 60 feet long, will cost 900*l.* each	37,800
To an extra double lock for a double entry, at Grange burn foot, with extra expenses in diverting the burn	1,800
To making an aqueduct bridge over Grange burn	400
To extra digging in passing a narrow gripe between two rising grounds, west of Mungull's house	100
To extra digging through the summit of the ground between Glenfour and New Hall, above Camelton	100
To extra banking across seven hollows betwixt New Hall and Bonnie mill, and one small rise	600
To an aqueduct bridge in passing Bonnie mill burn	1,250
To extra work in passing Seabeg's Wood, Trannock burn, Acre burn, and some other hollows and rises from thence to Castle Cary bridge	400
To an aqueduct bridge for passing the River Bonnie, near Castle Cary bridge, and extra banking there	1,000
To extra cutting in the canal of partition, so as to make it a 50 foot bottom	1,478
To defending the dam-heads and banks of the reservoir with stones against the wash of the waves	300
To making two dams, one at each end of Dolater bog, so as to form the whole into a reservoir	1,408
To making a sluice for drawing the water from the reservoir into the canal of partition, and over-falls for discharging the water each way	100
To building a dam and other works at Inch Belly bridge, for the passage of the canal there	500
To extra expenses in passing the river Loggie at Kirkintulloch	300
To a dam and works at Calder bridge	500
To extra expenses in cutting the hill in the Allander passage, near New Kilpatrick, computed to be 35 feet above the bottom of the canal, the digging being estimated at 6*d.*, and the walling at 5*s.* per cube yard	8,166
To extra expenses in cutting the hill at the weaver's house, above Grascuddon, with some other inequalities there	250
To extra work in making a jetty, in order to defend the mouth of the canal from the lodgment of sand, and clearing a passage into Clyde	150
To extra cutting in passing the rising ground opposite Blart hill, and in altering the turnpike road upon the Glasgow branch	600
To building an aqueduct bridge over the river Kelvin, in order to carry the canal to Glasgow, including other expenses in passing that place	3,500
To making aqueducts and trenches, with such tunnels and bridges as may be wanted, for bringing the several supplies proposed, into the Dolater reservoir	500
To six public road draw bridges, or turning bridges, viz. that at the road from Falkirk to Carron and Stirling, at Camelton, Inch Belly bridge, Calder bridge, and Brick-house, upon the road from Glasgow to Dumbarton; also one upon the branch canal, where the same road intersects it near Blart hill, at 600*l.* each	3,600
To 10 draw, or turning bridges, of lesser dimensions, where the lesser roads intersect the canal, at 400*l.*	4,000
Carried forward	125,818

Brought over	125,818
To 21 carriage bridges for communication between the lands	5,250
To 15 large tunnels for communicating the lesser brooks under the canal, at 60*l.* each	900
To 59 small tunnels for preserving present watercourses, making, with the large ones, at the rate of two in a mile, at 15*l.* each	885
To making towing paths, back drains, gates, towing bridges, &c., at 20*l.* per mile	740
To bringing the water of Enrick from a little above Randeford into Carron	150
To bringing the burn of Ballagin, with some springs rising out of the hills to the north-west of the spout of Ballagin, that now fall into the water of Blain into Kelvin	100
To making trenches, sluices, &c, for drawing off the water of Bishop's loch, and three others in that neighbourhood, in case they should be wanted	100
To temporary damages, unforeseen accidents, impediments, and works, engines, utensils, and surveyor's salaries, supposed at 10*l.* per cent.	13,394
N.B. Exceptions as before	147,337

Austhorpe, 8th October, 1767. J. SMEATON.

A REVIEW

Of several Matters relative to the Forth and Clyde Navigation as now settled by Act of Parliament, with some Observations on the Reports of Messrs. Brindley, Yeoman, and Golburne, by John Smeaton, Civil Engineer, and F.R.S.

I now sit down, at the recommendation of the committee of the Forth and Clyde navigation, to consider the reports of Messrs. Brindley, Yeoman, and Golburne, and (as desired) to make such observations thereon, and answers thereto, as to me shall seem proper. I shall, therefore, endeavour to acquit myself of this business, not altogether by pursuing the questions and answers in the order in which they have been produced, but by endeavouring to bring the main things as much as possible into view.

The most material point, as it occurs to me, is concerning the place of entry at the Carron end of the canal; and the question seems not whether the entry ought to be at the Hewk farm, or further up the river, at or near the Carron establishments: but whether an entry at or near the Carron establishments alone, will not be preferable to an entry at each of those places.

It has been given out (and I find Mr. Yeoman touches upon it), that the places of entry were not of my choosing; and as they differ from the places pointed out in the plan contained in my first Report, that this deviation is contrary to my own opinion, and wrong in itself.

In order to clear my way through the whole of this question, I beg leave to premise, that when I made my first Report, the two great difficulties that were apprehended were money and water; of the latter I found a sufficiency, but of the former I had great reason to be apprehensive there would be no superabundance; and as the sort of vessels, size of the canal, and species of navigation, were entirely left to my choice by the board of trustees, who then did me the honour to employ me, my endeavour was to produce a scheme which was likely to answer the end proposed, viz., a general communication between the two seas, and which as such could be executed at the smallest expense.

In this view of a general communication between the two seas, it seemed to me a *sine quâ non*, that it should be of a sufficient size to carry such vessels as could

freely and securely navigate the two Firths, whereon the two ends of the canal must terminate; for by this property every port on each of the Firths will in a manner become a harbour to the canal, and partake of the benefit thereof, in proportion to their more or less advantageous situation: whereas a canal of a less size, capable of admitting such vessels only as would navigate the canal, without being capable of navigating the two Firths, could never be considered as a general communication between the two seas, but only as a particular communication between two places, one at each end of the canal, and each communicating with the respective seas; and which places would thereby reap, in a manner, the whole benefit; and more especially so, if the points of termination were drawn into such shallow water, that no other port or place could avail itself of the passage without the use of mean or intermediate vessels to carry goods from the principal seaports, where large vessels could be received to the respective entries of the canal, which double transhipping would lay such a weight upon the out-ports, as would in effect become an entire monopoly of carriage between the two places of termination.

As I neither was at that time, nor profess now to be, so far master of the general art of constructing vessels for navigation, as to assign the measures most proper for each particular service, and finding the artists themselves in these branches to differ in their opinions, those who have been chiefly in the practice of building flat vessels for shallow water, attributing properties thereto which are by no means allowed by those who are in the habit of building sharper vessels for deeper water; and being willing to found myself upon secure principles, I took the ga boats or galberts of the river Clyde for my model: knowing that the daily practice of these vessels was to carry goods between Port Glasgow and Greenock to Glasgow, and I was informed they occasionally went to much more distant places upon the Clyde, and even to Ireland; knowing also, from a former acquaintance with the river Clyde, the difficulty of getting up these vessels to Glasgow in dry seasons and short tides: I took for granted that these galberts were constructed upon as flat a model as would answer the purposes of the navigation in the open Firth; and as I found they drew at a medium about 4 or 4½ feet water, I concluded that a canal of 5 feet depth of water would give such latitude in point of construction, that my principal view could not miss of being completely answered, that of a free, open, and general navigation, between every port on the Firth of Clyde, to every port on the Firth of Forth.

It is true I know of no such vessel on the Firth of Forth; the flatness of the river Clyde, some miles below Glasgow, having produced the necessity of using galberts on that Firth; yet, by parity of reason, I supposed them as capable of navigating one Firth as the other.

Having thus found myself in possession of a vessel, which, though the smallest that would effectually answer my view of a general communication, was yet considerably more bulky than those commonly used in the artificial navigations in England; and as the bulk, weight, and expense of those works must increase in proportion to the weight of the vessels that are to navigate through them, this occasioned me to conclude that these were the largest size that would be convenient for an artificial navigation. See first Report, page 299, and second Report, page 321.

The twofold view of a general communication, and at the least possible expense, determined me likewise with respect to the places of entry. I was not insensible at that time, that if the places were so chosen, that the vessels could enter at all times of tide, it would be preferable to their entering at high-water only, at neap tides; but the extensions necessary to produce this, seemed to me likely so much to swell the expense, that I laid aside every thought of that kind, and contented myself with

proposing such places as afforded a secure entry at the high-water of neap tides. This produced the proposition of an entry a little above Abbotshaugh, at the Carron end; for though the tide navigation might have been continued a little further up, yet the ground for a departure appeared to me far less proper. With respect to the entry at Barns of Clyde, that could not properly be carried higher on account of a shoal just above, where the galberts are stopped at short tides; and though the city of Glasgow had at that time an act of parliament which authorised them to deepen the river, which might have enabled the entry to have been made nearer Glasgow, in case that had been performed; yet, as the magistrates of that city had laid aside their prosecution of that work for some years, after it had been put in hand under my direction, I could not think it right to advise my employers to build any part of their scheme upon one which another set of gentlemen had it in their power to execute, or not, as they thought proper.

These were the general views and ideas upon which my first plan and Report were built, which were delivered to the honourable board of trustees for fisheries and manufactures in Scotland, in March 1764; it now comes in course to shew my reasons for the deviations from the above plan, as per second plan delivered in the month of October 1767.

But first I must premise, that in whatever character my brethren may be ambitious of acting, I leave that to them; for my own part, I shall take this opportunity, as I find gentlemen apt to mistake the character in which I am desirous of appearing, to declare that I do not act in consequence of any public authority or commission, to inquire, determine, and declare, what is best for the public, or what in its consequences will assuredly promote its good. I should indeed be very sorry to have so great a weight laid upon my shoulders, which neither my studies nor inclinations have qualified me to undertake. I consider myself in no other light than as a private artist who works for hire for those who are pleased to employ me, and those whom I can conveniently and consistently serve. They who send for me to take my advice upon any scheme, I consider as my paymasters; from them I receive my propositions of what they are desirous of effecting; work with rule and compass, pen, ink, and paper, and figures, and give them my best advice thereupon. If the proposition be of a public nature, and such as involves the interest of others, I endeavour to deliver myself with all the plainness and persipicuity I am able, that those who may have an interest of a contrary kind, may have an opportunity of declaring and defending themselves. I do not look upon the report of an engineer to be a law, at least not my own. As a proposition, every one has a right to object to it, and to endeavour to prevent its passing into a law, or to oppose its execution in such a way as may be detrimental to others: had, therefore, Messrs. Brindley, Yeoman, and Golburne, been sent for in consequence of my second Report, published in 1767, in order to have examined the matter thereof, and to have enabled those who might think themselves concerned to oppose the proposition, nobody could have objected to such a procedure; but, after the proposition has been suffered to pass into a law, and thereby tacity assented to, to send for engineers to determine whether the law itself be rightly founded, and to prevent the execution till that be determined, is, indeed, to me a very extraordinary evolution, and a sort of proceeding which, as I think, every well-wisher to the success of the scheme should set his face against. Had the matters objected to been different in the act from the scheme, or had the execution of the act differed from the act itself, there had been some colour for this interposition; but, if not, and if it was as well known that the Hewk farm belonged to Sir Lawrence Dundas, in October 1767, as that the estate of Abbotshaugh belongs to Messrs. Garbett and Co.

in 1768, those manœuvres cannot now be looked upon other than an unseasonable interposition to stop the progress of the work.

Respecting the two schemes, I have no hesitation in declaring that my scheme for a general communication between the two seas, is contained in my first Report, that is, with such corrections as the difference of circumstances that have arisen since my first Report was drawn up, and better information might suggest; and that the enlargements upon my first plan and report were propositions given me by my employers, and I should be surprised, if this should be matter of news to any one concerned, since I have fully declared the same in my second Report, to which I refer; nor could I possibly see the matter in any other light, since the revisal of my first plan was undertaken in consequence of a compromise between the contending parties in parliament, at the close of the preceding session; one of which articles was, a branch to Glasgow of the same dimensions as the main canal, which, it is very probable, I might never have advised as a thing to be undertaken by the proprietors of the main work. The places of entry were, also, pointed out to me by the report of the committee of royal boroughs, which I have stated in my second Report, pages 329, 330, a copy of which, I received from Mr. CHALMERS, who, also, furnished me with the greatest part of the data, as stated in my second Report, upon which I proceeded; but I beg leave to say it does not follow, that because I did not form the propositions for enlarging my first scheme, I did not approve of them; the material question, I think, is not who formed the propositions, but whether the matter therein contained be right or wrong.

In regard to the increase of depth of water beyond my first proposition, I take it as a self-evident truth, that every increase of depth must be an increase of advantage to trade; but as trade is not my profession, I neither do, nor ever did, take upon me to determine whether any given increase of depth would be attended with an advantage equal to the increase of expense, and also length of time attending the execution: this I must leave to men of trade to determine, it is sufficient for me if I can compute what the difference of expense will be. It was, therefore, given me as a proposition to compute the expense of a canal of seven feet, eight feet and a half, and ten feet deep, in order that those whom it concerned might make their choice.

Respecting the extensions, it is impossible for me now to say what my ideas of the necessity thereof might have been, had not this part of the work been undertaken and prepared for me before my arrival, by the convention of royal boroughs. That "the greater the depth of water where the entries are made, *cæteris paribus*, they are the better," I could easily see without the help of the committee of royal boroughs; but in what degree trade would be benefited by a given difference of depth of water at the entries; or to say what difference of depth is to trade worth what sum of money; how far the cap ought or ought not to be put off to certain very respectable bodies of men, or the line drawn aside from the more general convenience,—are matters that might have puzzled me, had they been left naked to my determination. I therefore thought myself very happy that this part of my task had been brought to a point by so respectable a body of men, who, if I understand the affair, are a body incorporated by act of parliament, and have the sole power of regulating public matters of trade throughout Scotland, and whose authority, therefore, in this kind of matters I had reason to think so much better than my own. I can, therefore, only now declare the reasons that induced me to acquiesce in the opinions of these gentlemen respecting the places of entry; which, if I could not have done, I should certainly have thought it my duty to my employers to have declared.

In the first place, I found the number of vessels so much increased at Carron,

beyond what I had observed at Carron shore, when I was upon my survey in August 1763, owing not only to the increase of trade occasioned by an augmentation of iron works there, but more especially by the establishment of the Carron Ship Company since that time; that had my first idea of a five-feet canal, to be done at the least possible expense, been adhered to, I should certainly, on this review, have advised the entry to have been made below all the Carron establishments, in order that such vessels as wanted to pass the canal, independent thereof, might have room to go quietly by them. This, I say, must have been the case had the five-feet canal been adhered to; but as the proposition now was for a canal of at least seven feet, and of a depth of $8\frac{1}{2}$ feet, at a medium, as a much greater quantity and bulk of vessels must be expected in consequence of its admitting those of a sea construction, I did not, nor do I now think, that the new cuts through which the river is turned, which begin just below the elbow where the grounds of Abbotshaugh terminate, of sufficient width to afford a convenient resting place for such kind and sort of vessels as were now intended to navigate the canal: add to this, that but a little way below the termination of these cuts, there is the most remarkable shoal or ford upon the river, commonly called Jemmy Reay's Ford, upon which, at high-water at a neap tide, according to all accounts there is not above 8 feet water, and in low neaps short of that. As, therefore, the vessels proposed could not sometimes, even at high-water, pass this shoal, the great and uncertain expense of lowering thereof, so as to make it certain and convenient for vessels requiring any of the depths of water contained in the new proposition; and I may add, the not having a perfect certainty of its remaining so, even after cleared; made it seem to me very advisable, in a work intended for a general communication, to avoid all uncertainty of expedients, and to carry the canal below Reay's Ford. But, supposing that done, we cannot go above a quarter of a mile before we come to one of the most remarkable loops in the whole river, which either must be cut, or the navigation would remain inconvenient; and as my idea of the facility of cutting those loops, so as to make them suitable to the river, did not, nor does now, happen perfectly to correspond with those of my brethren, who have since been consulted, I was of opinion that the canal could be continued superficially upon the banks of the river at far less expense than this neck could be cut; and with this further, and very material advantage, that there is at least 4 feet more water to Grange burn foot than if dropped into the straight reach below Reay's Ford; this in consequence carried me down to Grange burn foot, to the place where the interior entry is now proposed. And as I neither did, nor do approve of making a cut for the river Carron across the Hewk farm, in order to make the entry of the canal perfectly convenient; and upon a supposition that money was not wanting, it did and does to me seem advisable to extend the canal across the Hewk farm to Holmerrie, because here vessels of seven or even eight feet water, instead of being confined to half an hour at the high-water of a neap tide, may go in at a neap tide low-water, which, in my opinion, is not only a great advantage, but I take the liberty of asserting once more, the outward entry will be attended with this further convenience, that a vessel which can go into the outward reach of the Carron, may enter the canal at the exterior, or if not there, at the interior entry: for these reasons I concurred with the committee of royal boroughs, that if general convenience be the object, and not saving money, which is a language not spoken of to me till lately, the canal ought to be extended to the Hewk farm.

It is very certain that, if the proprietors will abate of the conveniences of the canal, the expense may be considerably shortened: but I am not convinced that the expense will, upon the whole, be shortened by executing the alterations of the river Carron proposed by the three gentlemen, whose reports I have now before me.

I should be much surprised if any of the proprietors who have attended the business of the canal, should be uninformed that it would save expenses by beginning the canal higher up the river than the Hewk farm; but it is certain the conveniences are far from equal, as is apparent by the gentlemen taking so much pains to form expedients to remove, even in part, the natural difficulties which make the difference; and as to that part which they cannot remove, they tell you, that you will save money: they cannot say, they do not say, that it is as good to enter where you can go in at the high-water of a neap tide only, as it is to enter where you can go in at the low-water of a neap tide; but they tell you, that if you will give up this advantage, you will save some extent of canal (made upon the superficies of the ground, where it is most easy); and you will save the locks, whereby you would be enabled to go down into deep water: why, truly, we knew all this, without Mr. BRINDLEY, Mr. YEOMAN, and Mr. GOLBURNE. How much of convenience to trade is worth how much money, I have already said, is not in my power to estimate; it is enough if I can make an estimate of the cost of what, I beg leave still to say, is the most complete; whether this be, or be not worth the money, I leave to men of trade to judge. For my own part I choose to build my designs upon sure grounds, whenever sure grounds are to be had; it is time enough to apply to expedients when we can do no other; that what is proposed are but expedients, the gentlemen themselves who propose them apprehend; because they desire the works may be stopped till it is seen whether they succeed or not.

In regard to the Clyde, I think it stands confessed that in its present state, an entry suitable to a canal of even seven feet constant water cannot be made materially higher than Dalmoore burn foot, and, even thither, there is not that ample sufficiency of water which is to be wished; could it have been extended from Dalmoore burn foot, into as good water as is at Hewk farm, at an equal expense to the probable difference between beginning at Abbotshaugh and Hewk farm, I should not hesitate to advise it, if the money could be procured to do it. This, I say, is the case according to the state in which I found the river Clyde in the years 1763 and 1767, and to have built any part of a scheme of this still greater extent, upon what the magistrates of Glasgow had it in their power to do, or not, at their pleasure, and which they might or might not be able to do, would, in my opinion, have been very indiscreet in me to have recommended. Mr. GOLBURNE had not been upon the Clyde at that time; and, if he had, it would have been no demonstration to me that making a channel for vessels drawing six feet water was making seven feet water, since the galbert men could have told him that if they have an inch to spare, they never stick fast upon a shoal: be this as it may, if he can, as he says in his report, bring up vessels drawing six feet water to the Broomie law at all tides, (and as is said for him, without lock or dam,) for the sum of 7000*l.*, he will do a thing remarkable in itself, and a good thing for the city of Glasgow, and in which I wish him and the city of Glasgow much success: when that is done, the branch canal may be shortened several miles, by dropping into the river Clyde just below Blart hill: but as I like to work upon safe grounds when I can, Mr. GOLBURNE must excuse me if I cannot recommend to the proprietors to give up their entry near Dalmoore burn foot, or stop their proceedings in joining the two seas, until he has brought his scheme to bear. Having now shewn the reasons why my plans have been what they are, and in particular why I did not dissent from the committee of royal boroughs in regard to the places of entry; and in the course thereof why I think a compound entry at Hewk farm, at Grange burn foot, and one nearer the Carron wharfs, preferable to a single entry near the Carron wharfs only;—I shall now proceed to make some observations upon the most material points wherein I differ in opinion from my brethren.

1st, 2d, and 3d. With respect to the answers to the 1st, 2d, and 3d queries, I do not find that Messrs. BRINDLEY and YEOMAN have controverted any material point by me laid down; I have only to observe, that though they both in effect allow that they have not examined the sources of water with that exactness that I have done, yet they admit that 100,000 tons of merchandise may be carried annually from sea to sea each way, whereas the quantity I have estimated is no more than two-thirds of 100,000 each way. See second Report, page 322. I do not mean, however, to contradict them.

4th. Mr. BRINDLEY recommends a canal of four feet deep, and vessels drawing three feet water to be seven feet wide, and seventy feet long: this would be a very effectual way of securing the use of the canal to the two terminations: no port but that of Carron could have the least chance, for since this kind of vessels could scarcely venture out of the narrow cuts, not even below Jemmy Reay's ford, in a windy day; the large vessels that now come to the Green brae (that is, the natural harbour, consituted in the reach within the Hewk point), would be obliged to employ a mean or middle sort of vessel to carry the goods from the ship to the entry of the canal, and the same at the other end thereof: as to the ports of Leith, Borrowstonness, and many others upon the Firth of Forth, together with Greenock, Port Glasgow, and many others upon the Firth of Clyde, they would have no chance, even Glasgow would stand but a bad chance without a side cut of equal dimensions, or the main canal itself terminated there.

In this case Mr. BRINDLEY would have done well to have recommended the sort of restraints that he would advise, to prevent monopolies and impositions at wharfs and warehouses, since nobody but those at the terminations could have any business there. Mr. YEOMAN agrees in thinking the seven-feet canal to be most proper, and Mr. BRINDLEY, that it should not be exceeded.

N.B. As no difficulty is too great for Mr. BRINDLEY, I should be glad to see how he would stow a fire engine cylinder, cast at Carron, of $6\frac{1}{2}$ feet diameter, in one of his seven-feet boats, so as to prevent its breaking the back of the boat, or oversetting.

5th, 6th, 7th, 8th, 13th, and 14th. There is no doubt but that the cutting of the neck of land, referred to in the 5th question, will be a very great improvement to the navigation of the river Carron, up to Carron shore; because I look upon it that vessels find far more embarrassment and difficulty in getting round this loop, than in all the rest: and I am also of opinion, that this may be done without prejudice to the canal, as now going on according to act of parliament, provided proper caution is used, and the undertakers laid under proper restrictions; and it is a work that I am told Sir LAWRENCE DUNDAS did propose to have done at his own charge; but with respect to the cutting of the point of land from Grange burn foot to Holemerrie, or taking the two necks together in one sweep from above the upper Salmon Zair to Holemerrie, I cannot, by any means, agree with my brethren in opinion; but that, instead of making an excellent harbour of two miles, they will entirely spoil a good harbour, which is now furnished by nature ready made.

I believe it may be laid down for a general rule, that all small harbours have some inconveniences (small I call that at Green brae in comparison of Milford Haven), for the same means that render them more secure for vessels when in, in general render them less accessible, especially by some particular winds.

With respect to vessels intending to enter the canal, there is no difficulty; they can always enter by either the exterior or interior mouth of the canal, or one of them, whenever they can get up the sea reach, or mouth of the river Carron, as

before taken notice of. I must observe that the sea reach is wide enough for vessels to turn to windward, but that in the reach next above, leading to the Hewk point, the channel is too narrow for large vessels to do it, and troublesome for small ones, unless we except at or near high-water spring tides. It will, therefore, happen, that when the wind blows right down this reach, which bears S.SE. and N.NW. or, indeed, within six points of the compass, that there will be a difficulty in getting vessels, especially large ones, up this reach; but then it is to be observed that this reach, lying nearly parallel to the Firth of Forth, nearly the same winds that hinder them sailing up this reach will also be against them sailing up the Forth to Carron mouth; however, as there is ample room in the Firth of Forth for vessels to turn to windward, I do admit that it may happen that vessels may get into the Carron mouth, when they cannot get up this reach; but in all these cases, as the wind will blow over land, this reach will be a place of safety for such vessels to lie in till the wind changes favourably; and, indeed, there is no occasion for their lying here, unless it blows hard against them, because the length of this reach is not so great, but that they may one tide of flood warp themselves in round the Hewk point, where they meet a safe harbour, and, in every respect, except the circumstances above mentioned, an excellent harbour, as is already found by the large vessels that frequent it, and deliver their cargoes at the Green brae, a harbour capable of taking vessels at spring tides of five or six hundred tons, and of three or four hundred tons (according as they are built), at neap tides. The author of a tract now before me, seems to have been fully sensible of the importance and excellence of this harbour; when speaking of the river Carron, he says, "within the mouth of the river there is a most capacious station for ships of any burden, of about half a mile in length, having from twenty-two to twenty-four feet water in spring tides, and from sixteen to eighteen in neap tides.

"Further up the river (near the place where the canal is intended to come in, and where the Carron company have built wharfs or quays for the export of their iron and other manufactures), the harbour has been greatly improved by cutting one large loop, and there is another now cutting in the river (both at their own expense), which will make twelve feet water in spring tides, and eight feet in neap tides."

"The harbour of the river Carron is capable of containing 1000 sail of ships, and the boats using the canal may sail to any one of them, whether they be at the entrance of the canal (where ships using the coasting trade do now come up), or at the mouth of the river at Green brae (where ships, drawing from twenty to twenty-four feet water, of 500 or 600 tons or upwards may lie), and this without any expense of lock dues, &c. as the river is a free navigation."

Who was the author of this tract I know not, but when I was upon the view of the river Carron, in August 1767, it was put into my hands by Mr. GASCOIGNE, as a thing whose truth was not to be questioned: it is entitled, "A short Description of the Harbours of Borrowstonness and Carron, with a comparative View of their Importance with regard to the communication between the east and west Seas." Moved with the truths above referred to, I was very unwilling to propose any thing to the detriment of this most useful and excellent harbour, and, being at the same time as great an enemy to monopolies and impositions at wharfs and warehouses as any of my brethren, I was willing to take the advantage of this harbour in such manner, that a great part, if not the greatest part of all the goods that will require transhipping in the Carron, may be done without the use of wharfs and warehouses at all. This part of the river, which alone can be properly called the harbour of Carron, is of a considerable width, the bottom every where a soft mud, easy for

vessels of all kinds to lie upon, and is divided into two channels by a bank also of soft mud, upon which there is fourteen feet water at spring, and nine at neap tides, according to soundings marked thereon in a plan annexed to the tract above mentioned; the two channels are on each side near the shore, and are rather capacious than confined: it is not easy to say how wide they are, for, as the whole bottom is soft mud, which in course forms itself upon very gentle slopes, a very little difference in the flow or ebb of the tide makes a considerable difference in the width; however, as the whole bank is covered at, or soon after, the first quarter's flood, the river I suppose then to be at least 600 feet wide; what the precise width is, I cannot at present say, having not yet got any plan sufficiently exact to determine it; this, however, I know from inspection, that it is a great width, and apparently the widest part of the river.

The depth of the canal, as it is settled by act of parliament, and the width thereof, and of the locks as intended in consequence, are capable of carrying vessels built galbert fashion (and capable, in like manner, of navigating the two Firths), of 100 tons burden; such sea vessels, therefore, as cannot pass the canal, but want to tranship in Carron water, will lie in one of the channels, where they now do, and where one of these large galberts may lie alongside of them; or, if need be, one on each side at a time, from whence the cargoes can be transhipped from vessel to vessel, without the use of wharfs and warehouses, while the other channel and bank are left clear for the passage of vessels to the canal, or to Carron shore: nor can vessels for the canal be in the way of those going up the river; for, besides room for several that will be made in the tail of the canal exclusive of the river, whenever they are opposed by wind at the inner entry, they have a fair wind at the exterior: nor can there be any objection to this method of transhipping, since, in a manner, the whole of the coals of Newcastle and Sunderland are shipped in this way, and unshipped at London; and not only coals, but the India, and, in general, almost all the ships of large burdens that use that port. I beg leave further to observe, whenever vessels happen to be stopped from going round the Hewk point into the harbour, that they are at safe mooring in the Hewk reach, where they need not lose time, if this way of transhipping is used, as the galberts can go to them there, and make their entry good at the Hewk lock.

Let us now examine what my brethren would give us in lieu of these advantages. That the making a straight or curved cut, as they have proposed, will enable vessels to go up to Carron with the same wind that enables them to enter the Carron's mouth, or otherwise to be towed up by horses, I can in part grant; and that this will be an advantage to the Carron wharfs and warehouses, I can grant also: but it happens here, as in many other cases, that while one thing is mended, another is made worse; and it seems to me, that by the gaining this one advantage, of a more general entry, we shall lose all the rest. I wish my brethren had been kind enough to tell us, how wide at bottom and top they proposed to make this cut; because I must tell them, unless it is of very different dimensions from what is already executed as a specimen in the last new cut, I shall not like their project any better than they like mine. Mr. GOLBURNE, who seems to be the oracle in this part of the work, says "and by confining the new river on each side, the current will act upon the bottom and grind it down to a proper depth." This proper depth he nowhere tells us; however, it is plain enough he does not intend it to be very wide; and, indeed, that is shewn by his estimate for doing it; for, to make the bottom suitable to the bottom of the river at head and tail, it must be dug or washed away to the main depth of 20 feet below the surface of the present soil of the lands through which it is

to pass, the broken ground excepted; but, suppose there should happen to intervene some hard matter in the bottom, the current may then not act thereon, so as to grind it down to a proper depth, but, on the contrary, turn it aside, and make a fresh crook instead of the old one: such things may happen.

Now, I would be glad to appeal to any skilful and unprejudiced master of a ship, a person who has had the care of one of 300, 400, 500, or 600 tons, whether he would choose to lie in a gullet, where he cannot turn himself about, but if he goes in head-forward, he will be obliged to go out stern-forward, with large lighters or galberts by his side (or be obliged to lose this way), to tranship his cargo, and where other vessels of equal size will be obliged to rub by as well as they can; where he is subject to speats and floods coming down, which run like a sluice, as may be seen in the last made cut; into which floods in winter frequently bring down shoals of ice; and where, if the wind blows in or near the mouth of the gullet, the sea will have a fetch of three or four miles;—I say, I would be glad to ask any experienced and unprejudiced ship-master, whether he would look upon this as any harbour at all, especially for large vessels? Certainly, he would answer in the negative: then, pray, gentlemen, where is your harbour? Is it in the cuts now made above? no; these have the same objections, except that arising from the swell, with the addition of one still more in their disfavour, which is, that there is not water to get a ship of any burden into them. The harbour must be then in the open reach of the river, between the tail of the last new made cut and the head of the new proposed cut; but it must be below Jemmy Reay's ford: in short, it must be confined to a space in the natural river not above 200 yards in length, and where there is not above eleven or twelve feet of water at a neap tide, this very difficult of access in time of floods and speats, occasioned by a long narrow entry, and this is your excellent harbour of two miles in length! excellent, indeed, for the Carron smacks, as it will be the most likely means of banishing all larger vessels. Oh! but Mr. GOLBURNE proposes to clear away the "stones and hard gravel near Reay's ford," by "dredging or ploughing, as shall be most convenient;" but I can tell Mr. GOLBURNE, that he must dredge or plough, which ever he finds most convenient, and that pretty deep, too, in some places, a great part of the way between Reay's ford and Abbotshaugh, in order to get two feet more of water than there now is. Mr. GOLBURNE says, that the expense of cutting and completing the new channel will not exceed 3000*l.** But he does not say how much the dredging or ploughing Reay's ford, &c. will cost; nor whether the dam to be erected across the river Carron, in order to force the water through the new cut, is included; nor how often that dam may chance to break down, before the Carron will submit to be controlled by it; nor how long the navigation may chance to be stopped after the dam is erected, while the channel is grinding down to a proper depth.

Mr. GOLBURNE computes that there must be seven feet water in the channel of the Carron at neap tides, so that vessels drawing six feet run up the river at low-water. Does Mr. GOLBURNE mean that they now do so, or that they will do so when the cut is made, and Reay's ford dredged? does he mean at the Carron mouth or at Reay's ford, and quite up to the Carron wharfs? for I own myself perfectly at a loss to understand both the logic and the arithmetic of this paragraph. This, however, I am certain of, exclusive of theory, that, instead of three feet water at low-

* Mr. GOLBURNE allows 100*l.* a-year for maintaining the new cut, which in effect is equivalent to a capital of 2000*l.*, so that the capital laid out upon completing this new cut will be 5000*l.*, a sum very far exceeding the extra cost of conveying the canal upon the surface.

water, upon Reay's ford, I have been carried over the river upon a man's back, when he was not wet above half-way up the leg; and, as there is not above eight feet water at high-water over Reay's ford, I do know by the help of a little theory, that Reay's ford, must be lowered about ten feet to make seven feet water at low-water neap tides in dry seasons, which I believe is far lower than any part of the bottom of the river above Reay's ford, and will not cut itself out till a great way below it. Reay's ford is, I believe (unless it is some accidental matter that may have been thrown out of the new cut which I reckon not upon), the shallowest part of the river, but I did not find, when I sounded it in 1767, above six inches of clear navigable water more above than at Reay's ford.

I can readily agree with my brethren, that this new reformed Carron will afford an excellent harbour of two miles for a particular sort of vessels, and had I, with them, viewed those vessels through the same optic glasses, I might have thought all others of little consequence, when seen through the opposite end; so far so good; but what it was that could provoke my brother BRINDLEY to call the present intended canal, a canal without a harbour, surprises me. Had Mr. GASCOIGNE put the same little tract into Mr. BRINDLEY's hands that he did into mine, I hope he would have had a better opinion of the harbour of Green brae; but perhaps the wind may be changed, and now blow right down the Hewk reach, and very hard, so that no vessels can enter; however, if he has no opinion of that, I must beg leave to inform him that I look upon the harbours of Leith and Borrowstonness, Port Glasgow, and Greenock, as well as many other harbours upon the Firths of Forth and Clyde, to be harbours to the canal, where they can tranship their goods on board of vessels; that whenever they can sail up the Forth and enter Carron mouth, they can enter the canal by one of the Hewk entries, or, if they like it still better, by the Carron entry, without troubling any wharf or warehouse, and by this means many trading places will partake of the benefit of this public spirited canal.

Mr. BRINDLEY and Mr. YEOMAN both agree in saying, that the alteration of the river will not produce a bar. I cannot say it will; but this I say, that I do not know any thing more difficult to pronounce upon than the effects that attend alterations of natural rivers; and I appeal to them, whether they do not, as I do, find, that even alterations of the simplest kind are often attended with effects that were not foreseen. This I know from experience, that whatever increases the rapidity of a river, tends to form it into hills and holes; that the great quantity of matter that will be driven out of the new cut will be lodged somewhere; that the rapid water issuing from the tail of a contracted cut, will have a tendency to deepen Holmerrie, and deposit the matter at some distance beyond it, as happened on opening the last new cut, and, therefore, will naturally lodge it where the bar now is, consequently, will have a tendency to increase it; this is nothing but plain reasoning from plain matters of observation; let my brethren say otherwise.

I cannot quit this subject without taking notice of an assertion of Mr. YEOMAN, on the 14th article; he says, "there is but one wind that can carry a vessel round the Hewk point, or even abreast thereof, after allowing every possible advantage of tide and fair weather." The harbour of Green brae is, indeed, very difficult of access, if there is but one wind by which it can be entered, and even not that "in a gale of wind:" very hard indeed, brother YEOMAN! I marvel much how the Carron Ship Company carry on their very extensive business under these difficulties.

As to the sea reach, or Carron mouth, this is common to each project, and it is agreed that vessels can turn to windward therein; I have already stated that, to vessels going upward, the Hewk reach will bear N.NW. Neither brother YEOMAN

nor I, are obliged by profession to be complete seamen; but I would be glad to ask any one that is so, whether he cannot sail up such a reach with the wind at W. and also with the wind at N.E.; and with all winds from N.E. round to W. taking in all the eastern and southern points, in short, taking in twenty parts in thirty-two of the whole compass? and, as this reach has the Hewk farm on the larboard side, and a high steep bank of mud on the starboard, which is hardly covered at high-water neap tides, whether even he cannot sail in with those winds, even in a gale of wind? also, whether, when at the head of this reach, a ship sailing in with a fair wind and tide of flood, may not shoot up sixty or seventy yards, so as to come abreast of the Hewk point with the wind right a-head in the turn of the point, where she will be at least in perfect security, and from whence she may, if she pleases, warp herself to her proper birth, if she wants to stop there? nay, further, whether small vessels, drawing seven or eight feet water, may not, where there is a breadth of four or five hundred feet, and a depth of at least 8½ or nine feet at a neap tide high-water, turn to windward, and weather this point; or work up the Green brae reach, if the wind being favourable in the former, and the turn of the Hewk should be right down that; and this, even though a tier of ships and lighters should occupy the channel on one side? Those that deny the practicability of doing this in water perfectly land-locked, on all sides a clear shore, and nothing but soft mud to run upon; let them attend to the narrow passage often left between the tiers of vessels in the port of London, through which vessels of large sizes are obliged to work when the wind is foul, or to the narrow passage into the port of Shields, from the Black Middins to the Hird Sand; nay, further, whether a vessel, before or after it has gained the Hewk point, may not as easily be towed by horses through a large open river to the Grange burn foot, as it can through a narrow cut from Holmerrie to the same point; especially with a flood in the river? As to any improvement above that place I oppose it not.

9th and 10th. I do not materially differ from my brethren, in answer to these questions; I have only to observe, that the land cannot be gained at a small charge, nor in my opinion in a small space of time.

11th. If cutting through the very tract proposed for the canal, or intersecting of it twice with the new cut, will be no obstruction to it, I do not know what will: I am, therefore, perfectly at a loss to know what my brethren mean by asserting that it will be no obstruction.

12th. No more than will be according to the present design, as every one will lie as commodious for the Carron entry if they do not choose the other.

15th. The greatest part of what can be said on this head, has been already said; I must, however, here take notice, that though both Mr. Brindley and Mr. Yeoman join in asserting that there will be no more obstruction from floods than at present, yet I would ask them whether the same quantity of water, passing through a small channel, must not move with a proportionably greater velocity, than in passing through a large one? and desire them, or any one else, to look at the last new cut in time of floods, and then tell me whether there is not more shelter for vessels from floods, and from ice in the eddies, occasioned by the turns of the river in its present state (and a greater length, too), than can be in a confined cut, in a right line, or so nearly so, where they can escape no part of it? I do not contend, however, that the river should be crooked, otherwise than to preserve the natural advantage of the harbour of Green brae.

16th. Some attention and some expense may be necessary, and I dare say any of my brethren can tell me how to do it, whenever it becomes necessary; but upon what foundation Mr. Brindley says, that, in case the river should break through this point,

" the lock intended to be built at Grange burn would then be left inaccessible to vessels drawing six feet water," I cannot conceive: had he sounded the Grange burn for a quarter of a mile upward, he would have found so much water, as, with his management, would have been able to have procured a passage of twice six feet of water.

17th. The connecting any side cuts, or cuts of communication, with the main undertaking, which I always understood to be a direct communication between sea and sea, was never according to my sentiments or advice. The Glasgow branch was a matter of necessity, arising from prior stipulation between parties, the end of which I never hesitated to say would, in my opinion, be more properly answered by the magistrates of Glasgow putting their act in execution for improving of the river; but who can compel them? With respect to the Carron entry, it was no part of my plan; nor the connecting of it, as to proprietorship, with the main canal, any part of my advice; if, therefore, the gentlemen have, without being fully advised of the nature of the ground, inadvertently agreed to a thing that will lay any degree of embarrassment upon the main design, it is no fault of mine. In regard to the agreement referred to, I never had any copy of it, except one delivered me some months ago by Mr. GARBETT, and which I profess myself not to understand. I have, at a public meeting of the proprietors, desired an authentic copy, with the precise terms of its meaning, but have not yet received it; and till then, I do not think myself justified in making any alterations in the track of the canal, or in taking notice of any paper that shall be delivered me by any person, whether proprietor, or not, unless it comes to me authenticated as by the act is directed; and, therefore, till I do receive an authentic copy, and be made to understand what is meant to be executed by those alone whom I acknowledge to have the power to direct me, I cannot advise what is most proper to be done in the case as it is now circumstanced: but thus far I can advise, that if the proprietors do not think proper to confine themselves to a sole entry at Carron, I do not think the track pointed out by Mr. BRINDLEY to be the advisable one.

18th. Respecting this article Mr. BRINDLEY says in his preface, that his time would not permit to make " minute examination of the strata of the earth;" yet, under this head, he says, " As I find the materials at the summit (or point of partition) very favourable, I recommend deep cutting at that place, not only for the saving of lockage, but with a view of acquiring very considerable quantities of new water." Mr. YEOMAN recommends to cut as deep as we can, not so much with a view to save lockage, as to acquire more water. Mr. MACKELL reports, from his examination in the summer, 1767, that the crust of peat earth is generally not above five feet thick, and under that, in every place he tried, there was quick mud; and as Mr. BRINDLEY acknowledged verbally, that in such a soil deep cutting was not to be recommended, or any material quantity of water to be expected, there is an end to this business of deep cutting. I wish it may prove more favourable; but, unless we can cut so deep as to save a lock's height, the rest will be no saving at all; and as to water, I should be surprised if we did not raise some, to which I hope we may be justly entitled in consequence of what is remarked in pages 322 and 323 of the second Report; but I think much water is not to be expected; because, if any communication with the hills produced any considerable pen, it would soon find its way through so thin a crust, and shew itself, especially as this crust has frequently been perforated, in digging peats. It is probable a quantity may be lodged under the crust, which may lie there inclosed, like water contained in a bladder, but which, when let off, there is an end of.

19th. Upon this query the two gentlemen seem divided; Mr. BRINDLEY recommends to begin at the point of partition, because, he says, it is his "constant practice to do so, and, in the present undertaking, it seems particularly advisable on many accounts:" but pray, Mr. BRINDLEY, is there no way to do a thing right but the way you do? I wish you had been a little more explicit on the many accounts; I think you only mention one, and that is to give more time to examine the two ends; but pray, Mr. BRINDLEY, if you were in a hurry, and the weather happened to be bad, so that you could not satisfy yourself concerning them, are the works to be immediately stopped when you blow the whistle, till you can come again, and make a more mature examination? and, further, do you usually begin at the most difficult part of a work first, with raw hands, before they are trained to business? I have sometimes done so, and repented it. I think it no difficulty to make a hole in a hard or soft rock, because it is every day's practice; but I do apprehend some difficulty in getting even the necessary depth into Dolater bog, notwithstanding you find the materials there so very favourable. Mr. YEOMAN very judiciously and very candidly observes (and in that spirit all his remarks and answers are drawn up), that as he apprehends "in a country like this, where the canal is to pass through, it will be utterly impossible, at least it will be very inconvenient, to begin any where, and carry on the works in a progressive manner, without some intervals, because of the want of accommodations for workmen, and especially at the first setting out." I have often told the proprietors that nothing of consequence could be done this year, but merely to make a beginning, and get the workmen into training, so that they may afterwards be branched off to different parts; that for the sake of getting accommodations for workmen, without laying a difficulty upon them and the country in supplying and lodging them, it would be right to put on workmen at both ends, the middle, and also to the neck of the hill in the Allander passage, by which means the work may be carried on in five different places: besides, men may be set to different stations to cut the trenches, aqueducts, &c., but all this cannot be done at once, nor is there any necessity of pushing, till the plans can be made out, several of which are already done, and in Mr. MACKELL'S hands, before I went last into Scotland; and one very material and much wanted, viz. for the locks, would have been done, had I not been employed in answering these Reports. As to what Mr. BRINDLEY throws out about making dry cuts, I will be bound to say that he will not finish the canal in four years, as he asserted; nor, as I think, in twice four, if he carries his work progressively each way from the summit, in order to take the water with him; and as to such opportunities of filling the cuts with water from the summit, or as offer themselves from the rains in the winter, we should have done that, though he had not told us. Something of this kind is to be found at page 323 of my second Report.

As to traffic from the summit, I have heard of none except Mr. CADDELL'S iron stone, which, as it only pays a penny per ton I must be so just to the interest of the proprietors who employ me, as not to tell them that I think this an object which should induce them to put their works out of the regular course of proceeding. I am obliged to Mr. YEOMAN in giving his sentiments of what he has seen done, and that whether in favour or disfavour.

20th and 21st. I have reported, and the engineers have confirmed it in their replies to the first and second queries, that there is water enough for the navigation, and to supply what shall be taken from the mills; the act says expressly, that all such water as shall be taken from the sources of the rivers Carron and Kelvin, to the detriment of the mills specified, shall be replaced in kind: this being the case, I do not see why the proprietors should be prescribed to, as to their mode of doing it.

If they are the showers the Carron company so much covet, we can give them sufficient of that from the head of the Enrick, to compensate the drainage of Dolater bog, and the hill sides along which the canal is carried; but as we propose to make tunnels and aqueducts to give the burns and runners their natural course, and to take nothing into the canal that we can help, beyond our proper supplies; and since all superfluous water taken in must be discharged at the overfalls, as it cannot be used, I would ask my brethren, whether, after this, a much more material drainage is not likely to arise from the soakage of the canal, and the Dolater reservoir, notwithstanding all the care and pains that either they or I can take? And since I have demonstrated, see second Report, page 325, that the Dolater reservoir alone will be capable of holding water that will supply the canal one quarter of a year, and all deficiencies for three quarters of a year, I hope we may take the opportunity of filling it in winter, or great downfals of rain, when twenty times as much water as they can use at Carron is running waste over the dam-heads, after all their reservoirs are full: it is our business only to give them as good means of filling their reservoirs, as they now have, not to enlarge their reservoir at Larbert, nor procure them Loch Coulter from Stirling mills; in short, I can see no other use of these two queries, but to raise difficulties where there are none.

I come now to take notice of such supplemental articles as my brethren have thought proper to add, which have not fallen in with some part of the foregoing observations. The principal is, they have found out a new road more near and convenient for the city of Glasgow; but I must beg the gentlemen to reflect, that whatever they have been upon, my object was a communication between sea and sea, and a branch to Glasgow, as per treaty. I have as high an idea of the trade and importance of Glasgow as they can have, and wish as well thereto; and for this reason, should have been most heartily glad that Glasgow had stood at Dalmoore burn foot: yet, notwithstanding all they have said, I can by no means give up the entry there; but as Glasgow stands not there, I further wish, that at any moderate expense, the canal could have been extended below Dumbuck.

The passage they hint at, and which is in some measure described by Mr. YEOMAN, is due to the assiduity and sagacity of Mr. MACKELL, who found it out after he left London, in the spring, 1767, and during the time he was employed in reconnoitring, previous to my review in August 1768, and who then shewed it to me; and it was shewn to Mr. BRINDLEY by Mr. LAURIE, the surveyor; and which passage, on consideration, I rejected for the following reasons:

1st. The ground from Calder bridge to the passage over Kelvin, at the Printfield, is in general rough, and some part of it very rough and crooked.

2dly. A rise of more than twenty feet, for near a quarter of a mile, above the level of the canal on one side, and almost as high on the other, but for a shorter length.

3dly. A very deep and wide valley to cross the Kelvin, by a very large aqueduct bridge.

These appearances made me judge that the expense of this passage would considerably exceed the expense of cutting the Allander summit, especially as I had then in view the carrying the canal upon a higher level, and saving a considerable quantity of cutting in that summit, and which I have now still more reason to think is practicable. Add to this, as we had no other view than to go to Dalmoore burn foot, it appeared to me not only considerably more winding, but further about from sea to sea, though Mr. MACKELL thought otherwise respecting the distance.

The communication to Glasgow would, indeed, be somewhat shorter; but then it parted from the main canal at such an elevation, as to require several locks to go

down to Glasgow, which would not only be expensive, but require water to work them; whereas, in the way the Glasgow branch was planned, it not only required no extra lock or water, but laid so nearly parallel to the river, that it might be used for a communication from Glasgow to Port Glasgow and Greenock, and back again; which, though no part of the stipulation, as I considered the branch canal as a dead weight upon the main undertaking, this circumstance might make it answer better, and be a proportionable advantage to the trade of Glasgow, there being no appearance then of the Clyde being improved. It was in vain to say—gentlemen, you may make a branch canal of your own river, by putting your act in execution. No; we must have a branch canal of equal dimensions. But if Messrs. BRINDLEY, YEOMAN, and GOLBURNE, have again caused the magistrates of Glasgow to resume the improvement of the river, as I am convinced, in my own opinion, that the track marked out in the act of parliament for the main canal, is, upon the whole, the preferable track; the truly wise and sensible thing will be to give the Glasgow gentlemen a branch cut, from near the three part mill dam into the Clyde, below Blart hill, as hinted at before; and though this will cost them at least three locks, with water to work them, yet the proprietors had better be at the expense of these locks, and procuring this water, than carry the canal over the Kelvin through the valuable grounds near Glasgow. Where Mr. BRINDLEY's canal was to terminate does not appear: this he has reserved for the next time he comes; but Mr. YEOMAN's termination at the Holme Sands I can by no means approve, not only because that is the most precarious part of the whole river, and because it lies in the power of other persons to remove the impediment or not, but, also, because there is another circumstance, that Mr. YEOMAN possibly was not acquainted with, which is, that if the magistrates of Glasgow only order the stones to be thrown into the river, that JOHN ADAM laid down at Marlin ford in the year 1760, for building a dam there, they may levy one shilling per ton upon all vessels passing that place, and thereby lay the canal under a heavy contribution.

That my brother BRINDLEY should prefer the Printfield passage I can readily comprehend: a late author has very solidly demonstrated, that every man, how great soever his genius, has a certain hobby horse that he likes to ride; a large aqueduct bridge over a large river does not happen to be mine, who am of opinion, that a given sum of money is as solidly laid out for posterity in cutting through the neck of a hill, as in building a bridge to carry water over water, though the admirers of the wonderful may not be so loud in their applauses.

As to Mr. BRINDLEY's 4th and 7th supplemental observations, which have not been touched upon before, I could have told him the same things if I had met with him in Staffordshire.

I ask Mr. GOLBURNE's pardon, for not attending before to one of his observations: he finds Holmerrie not above 100 yards long, and not above five feet deeper than the bar, whereas I have stated it at seven feet deeper than the bar, and a much greater length. I did not measure the length; but I sounded the depth, and found the deepest part seven feet deeper than the bar: this was during the very first speat that happened after the last new cut was opened, out of which first and last there has been driven a great quantity of matter: I therefore would ask Mr. GOLBURNE's opinion, whether some of the matter out of the new cut may not since that time have been lodged in Holmerrie, or that my pilots were as solicitous to find out the greatest depth, as his were to find the least? Be this as it may, the channel of the river in this place is for a great width deeper than the bar, and the bottom soft mud, so that vessels cannot be hurt in lying thereon, in three or four feet water at low-water, though Holmerrie should be quite filled up; or if two or three at a time, weaker

than the rest, cannot bear it, they may still find a birth in Holmerrie, in case Mr. GOLBURNE will not quite fill it up with the matter out of the new proposed cut.

Having now gone through every article that seems of consequence to the right understanding of the business in hand, I have only further to add, that for my own part I see nothing to oppose this great work being brought to a timely issue, but the different opinions of men; and I should not despair of seeing it executed, even with the remnant of time that I have in my power to apply to it, in case I am suffered to go on with the work according to my own experience and ideas; but, if engineers are to be constantly brought down to inspect and see how the pot boils, I think neither I nor any other man can go on with it, to the advantage of the proprietors, under such circumstances, any more than I could sit down at the cross of Edinburgh, and write this answer to my brethren, while every one at pleasure had an opportunity of overlooking and asking me why I begun this paragraph in this manner, or treated that subject thus. If, instead of making plans, I am to be employed in answering papers and queries, it will be impossible for me to go on with the business, and therefore, perhaps, those that wish no good to the undertaking may be desirous of furnishing me with this kind of materials. All the favour I desire of the proprietors is, that if I am thought capable of the undertaking, I may go on with it coolly and quietly, and whenever that to them shall appear doubtful, that I may have my dismission.

28th October, 1768. J. SMEATON.

COMPARATIVE VIEW

Of the Expenses upon the Works of the Forth and Clyde Canal, as per General Account, down to Christmas 1771, *with the Original Estimate:*

							£.	s.	d.
By account of materials, freight and carriage thereof, workmanship, digging, and temporary damages							71,747	12	2
Estimate of the whole, per second report					£.	147,337 0 0			
Estimate of additional expense of the new line, neat valuation						1,734 0 0			
Ten per cent thereon for contingencies						173 8 0			
Total sum estimated						149,244 8 0			
Total land purchase			13,544	0	0				
Ten per cent on ditto			1,354	8	0				
Deduct						14,898 8 0			
Total of materials and workmanship, valued per estimate						134,346 0 0			
Ditto of the Glasgow branch, deduct						13,007 7 4			
Remains for the main canal as now							121,338	12	8
Remains of the estimate to be expended							49,591	0	6
Difference of past expense and of that to come							21,155	11	8

N.B. If it is supposed that the works were half done at Christmas last, then the expense will exceed the estimate by about $\frac{1}{8}$. But if the expense of the Glasgow branch be given to this work, then the exceeding will be but about $\frac{1}{16}$th.

Edinburgh, 3d August, 1772. (Sic. subtr.) J. SMEATON.

A PLAN

Or Model for carrying on the mechanical Part of the Works of the Canal from Forth to Clyde, by J. SMEATON.

Engineer in chief.
Engineer resident.

Surveyor of the eastern department.	Surveyor of the middle department.	Surveyor of the western department.

To each of the surveyors, a foreman of the { Digging, Carpentry, Masonry.

Their duty as follows:

ENGINEER IN CHIEF.

1st. To make plans for execution of such works as shall be directed by the committee.

2dly. To pitch upon the ground whereon the said works are to be constructed.

3dly. To correspond with the committee upon such points as they shall think necessary.

4thly. To correspond with the engineer resident, and send such directions from time to time as himself or the resident shall find necessary.

ENGINEER RESIDENT.

1st. To attend such meetings of the committee as he shall be ordered to attend, or such meetings as he shall think necessary to procure directions.

2dly. To see the plans and directions of the engineer in chief put into execution.

3dly. To mark out the grounds to be purchased, and to enter into such treaty with the proprietors as he shall be directed by the committee.

4thly. To supply such plans and directions for the lesser part of the work as he shall be desired by the engineer in chief, or which his absence, or the necessity of the case shall make expedient.

5thly. To correspond regularly with the engineer in chief.

6thly. To give a monthly account of the state of the works to the committee, or oftener, if required, and to send a duplicate to the engineer in chief.

7thly. To attend each part of the work upon any emergency or difficulty, and also to see all new matters or methods put rightly in hand.

8thly. To survey the materials, and make such purchases thereof as directed by the committee.

9thly. To visit all the works from end to end as often as possible.

N.B. It is supposed that the resident engineer ought to have power of employing a land surveyor, if occasion, to measure and survey the lands, and to have power of discharging any officer under him on neglect of duty.

SURVEYORS OF PARTICULAR DISTRICTS.

1st. To attend to the orders of the engineer resident.

2dly. To see the proper quantities, qualities, and conversion of the materials committed to his care.

3dly. To order the foremen concerning the works whereon they are to employ themselves.

4thly. To transmit an account weekly of the progress of the works to the engineer resident, and of what materials, &c. are wanted.

5thly. To receive the necessary wages from the pay-clerk, and account with him for the money.

6thly. To reside as near as may be to the place where the principal works are under his care, to visit them daily, and the most distant once a week, or as often as possible.

FOREMAN OF PARTICULAR BRANCHES.

1st. To observe the directions of his surveyor.

2dly. To see all his men as often as possible, and to see that they keep to their labour.

3dly. To receive money from the surveyor, and pay the men, of whom he is the overseer, keeping a daily account for each particular man, and delivering a duplicate to the surveyor, in order to be transmitted to the committee.

N.B. As gangs or sets of men must necessarily be employed at different places under the same foreman, some one of these must be appointed overman of a gang: it is presumed that the overman may act as clerk of the check to his gang, and give an account of their time to his foreman.

To prevent abuses, the engineer resident to have inspection of all papers and accounts of the officers under him, whenever he thinks it necessary, or is ordered so to do by the committee.

London, 14*th March*, 1768. (*Signed*) J. SMEATON.

CALDER NAVIGATION.

The Report of JOHN SMEATON, *Engineer, concerning the State of the Calder Navigation, from a View thereof, taken the* 25*th and* 26*th Days of November*, 1767.

See a Map of the Calder, vol. i. plate I.

GREAT damages having happened, particularly to the banks and spade work of the Calder navigation, from a flood in the night between the 7th and 8th of October last; on a view thereof, I made the following observations: That the river was in this flood, by marks at Horbury mill, two feet ten inches perpendicular higher than any flood which has happened since the river was first surveyed by me in the year 1757; that at Minfield Low mill it was above four feet higher; and at Brighouse, three feet eleven inches; that, in fact, it was higher than any flood in man's memory, or of which there is any tradition, being universally allowed to be higher than an extraordinary flood which happened about forty years ago; which, in the neighbourhood of the Calder, is distinguished by the name of Bowman's flood, and which was always reported to me to be the highest ever known: but the flood of October last, by the marks at Horbury mill, (and the testimony of John Horn, a millwright, who has worked there and at Wakefield mills ever since Bowman's flood, and remembers it), appears to have been four inches higher at Horbury mill, than Bowman's flood,

and as in the late flood the rise was more considerable in the highest part of the river than below; these facts being considered, it seems more marvellous that the works have not been wholly swept away, rather than that they have been broken in particular places.

In order to guard the navigation as much as possible from such an extraordinary event as Bowman's flood was reported to be; it was always my intention, and which I have verbally mentioned to the commissioners, while I was concerned, that as soon as the navigation was opened to Brook's mouth, to build flood-gates like those at Dewsbury upper mills, at the head of Thorn's, Batty's, and Kirklee's cuts, and also to make up and defend the banks in particular places to an extra height and strength; and, had this been put into execution, I cannot help saying, that the damages on the present occasion had laid in much less compass, though probably not entirely prevented.

It appears from this view, that the banks for by very far the greatest part have withstood the flood, and that in those places where they have failed, it has not been by their bursting, but by the waters overflowing their tops, and have been either cut down in consequence of a current overflowing them, or beaten down by the waves raised by the wind, which, in the decline of these floods, was very violent, and which last cause of disaster might be prevented by covering them over with rubble stones, where so particularly exposed: it appears also, that nothing of consequence has happened to any of the capital works, viz. the locks and dams; for though two or three of the locks have suffered some damage, yet this has not been occasioned by any failure in point of construction, but by an attack from without, arising solely from the failure of the banks: the worst of these being Batty's lock, one of whose chamber walls was washed down piecemeal into the lock, by a current of water setting across the top of the wall, from a breach in the bank at the lock-head; yet even in this situation of distress, the pillars to which the gates were hung were left standing.

From hence it appears practicable, by guarding against the disasters that now have happened, partly by increasing the height and strength of the banks in particular places, and partly by the erection of flood-gates, not only in the three cuts above mentioned, but in some others that now appear to be much exposed, that this navigation might be made as safe against such floods as the great flood of October last, as it appears to have been before against all such as happen in the common course of nature.

The great difficulty and risk attending the navigation is during the course of the present winter, till the season comes in which the necessary works of safety may be performed; for till the breaches are made up, the navigation is liable to be interrupted, and what is already done in the way of repair, destroyed by common floods overtopping those places not fully made up, and this can only be prevented by a timely and speedy application of a sum of money to effect those purposes; and which, if speedily applied, and the season continues favourable, I hope will not be considerable in proportion to what has been already laid out: but as it depends upon circumstances of weather not to be foreseen; and when things are obliged to be done at a push, are necessarily done at a great disadvantage in point of expense, there is no possibility of making any regular estimate. But, supposing the navigation to be saved by a seasonable application till the winter is over, I am of opinion that the sum of 3000*l.* directly laid out during the course of next summer in erecting the necessary works and defences, will give a reasonable expectation of seeing such another flood pass over without interruption to the navigation, at least,

by the failure of any of its own works; for, it is to be observed, that by the failure of Dewsbury dam, belonging to Mr. Greenwood, the navigation would have been interrupted the greatest part, if not the whole time, that it may probably now be, had nothing particularly happened to the Calder works.

It appears to me, that eight, or at most nine pair of gates, with proper bankings in particular places, as before mentioned, will be sufficient, and all the materials being prepared and laid down upon the respective places, and the works divided into two, or perhaps three classes, that the works of each class may be got above water, without interrupting the navigation above ten days at each time, which, as it will be at intervals known beforehand, will, I apprehend, be no material detriment.

Gates upon Thorn's Ledger, Batty, and Kirklee's cuts, appear the most necessary; but I shall not prolong this discourse at present, by entering into the detail of what ought to be done in future; for in case this proposition is resolved upon by the commissioners, which seems to me the most likely, and, perhaps, the only way of giving a lasting security to the good effects of this navigation to the public, and to the property of those who have ventured thereupon: though I both am, and expect to be, much hurried in business, yet I shall not be wanting in giving my best advice concerning the proper placing and construction of the proposed works, if thereto desired.

Austhorpe, 30th November, 1767. J. SMEATON.

Mr. Smeaton, having viewed the River Calder, the 26th and 27th of December, 1770, reports as follows:

He has the pleasure to inform the company of proprietors, that he finds the river now put into as good a state of security as could possibly be expected in the time, and is, indeed, in general, in a very defensible condition; but to give the works every possible degree of security against the extremes of floods, he begs leave to subjoin the following remarks.

WAKEFIELD.

The heels of the flood-gates to be breasted up about one foot, and the banks made good to the bridge.

THORN'S CUT.

The flood-gates to be breasted and continued one foot higher to the high bank.

LUPSIT DAM.

The old setting in the body of the dam to be taken up and used as footing stones to a rubble body; the footing stones to be disposed in the arch of a circle, like the original dam, and from thence lagged up with an even slope to a proper height; the materials there rather want putting in order, than any great addition.

HORBURY BRIDGE.

The bottom, under the navigation bridge, to be filled with rubble, to such a

height as to allow navigation water only; this will strengthen the bottom when the water goes over the bank below next the land, and prevent so much from flowing through the bridge. The bank next the river from the bridge to the lock to be heightened by a new cover, and also a little above bridge to be raised, and to be rubbled next the river where worn.

LONG CUT.

The banks to be raised and strengthened a little above and below Mr. Walker's bridge.

The bank on the west side of the cut, for forty or fifty yards above where the old bridge stood, at Noel pond, to be a little raised with lagged rubble, so as to prevent the water going over that part before it does over the lagging at Noel pond.

BATTY MILL CUT.

About sixty yards of the bank, next the land below the bridge, to be lowered so as to be eighteen inches lower than the rest of the banking below bridge, and to be lagged over, that the back-water which, unavoidably, will get into the cut above, may be discharged there without breach of banks; the place in the bank next the river, just below the flood-gates, to be well secured by an addition of rubble, where it has been attacked by the late floods.

KIRKLEE'S CUT.

The bank on the south side the cut, above the flood-gates, to be rubbled over on the back side with small rubble, to prevent the wind wash of the water from taking it down when the banks belonging to the farm break above.

ANCHOR PITT.

Some rubble wanting to secure the tail of the dam's end wall, on the Bradley side.

LILLANDS.

The bank above the lock on the side next Lillands, to be made good with rubble behind the hedge.

GOOL CUT.

The bank next the river below the flood-gates to be made good to prevent the rivers breaking into the cut.

SOWERBY BRIDGE CUT.

When the water is off, to examine the places whereabouts the runs are, and to carefully tread and beat the earth that should line the same; if this is not effectual, a further deposition of ashes will be of use, and probably in time stop of themselves.

The method now taken of increasing the weight and strength of the banks, which slide on the side next the river, and diminishing those on the opposite side, is the most likely way to make them effectual.

It seems to me that water will be best brought into the cut from the river Calder, by carrying a sough through the high ground behind the housing of the town of Sowerby bridge; its dimensions and depth will depend upon the level, whether it can come from Sowerby bridge dam, or thither by an open cast from Holling's mill dam, and, if the latter, must be brought by a sough through the high ground contiguous to that mill, which level being taken, Mr. SMEATON will further advise.

AUSTHORPE, Jan. 16, 1771. J. SMEATON.

To Mr. THOMAS SIMPSON, Clerk to the Company of Proprietors of the Calder and Kebble Navigation.

THE REPORT

Of JOHN SMEATON, *Engineer, upon the means of Improving the Navigation of the Rivers Aire and Calder, from the free and open Tides-way to the Towns of Leeds and Wakefield respectively.*

FROM a careful inspection of these rivers, it appears to me, that the original projectors of the navigation, not having had any notion of the extensive trade that was likely to be carried on by means thereof, have formed their plan upon too diminutive a scale, and particularly with respect to depth or draught of water. This appears plain from this circumstance, that several of the thresholds of the locks have been laid so high in some of the most critical places, that, with full ponds in the ordinary state of the river, there is not above two feet six inches of water over the thresholds; and also not being aware that it would become the practice of millers to draw and keep down their ponds, in order to levy contributions on the navigation; though as to what concerns the working of the mills, it is manifestly their interest to endeavour to keep them full; the navigation has always laboured under difficulties on these accounts.

The level of the lock thresholds evinces what the views of the first projectors were respecting the construction of the navigation, and had this been the only fault, it would have been possible, by the rebuilding these locks, to have amended it; but the same idea, by endeavouring to save locks in point of number, and to save length of cutting, has tempted them to carry the locks too far upwards, so as to leave shoal spaces in the river for a considerable distance below.

Nor do these impediments last described occur only within the compass of the locks, or the artificial part of the navigation, for they equally subsist below the lowest lock, which is at Haddlesey; and though the spring tides there in ordinary make six feet additional water, yet the neaps do not commonly reach thither, so that in those cases in ordinary dry seasons, there will not be two feet of water up to Haddlesey lock at high-water neap tides: this is the case, not only within the limits of the present navigation, as subject to act of parliament, that is, down to Weeland, but there is also a considerable shoal equally as bad as any of the rest, that lies about a mile below Weeland, called Stock Reach, over which, though the neap tides sensibly flow, yet they do not make, in the whole, above two feet depth of water, and it is plain that no very material change for the worse has happened in the river since the navigation was begun, because the depth of water upon the lower gate threshold of Haddlesey lock corresponds with the present depth over the shoals afore-mentioned, nor would there be the water below the said lock, within the limits of the act of parliament, that there really is, were not the bottom of the river worn down at a place called the Hurst, by weirs, which at best do their business imperfectly, and are subject to be torn away by every land-flood.

To carry on a navigation under these disadvantages in dry seasons, they have early had recourse to flashes, that is, by drawing down the water out of such of the dams as were built by the navigation, and by doing this as it were altogether upon the two rivers, there is created in the spaces below an artificial fresh, which enables vessels drawing $3\frac{1}{2}$ feet water to move for a time; but, as the creating this fresh below drains the ponds above, they require, in dry seasons, such a length of time to fill that it frequently happens they cannot give above two flashes per week, and those flashes last but for a short space of time, so that vessels going down therewith, being crowded together, are unavoidably stopped in passing every lock; so

that, while that is doing, the flashes are spending, those that are foremost stand the best chance, while those behind are frequently catched by the keel: so that, taking the chances, they seldom get upon an average above two ponds per flash, going down, and in coming up, or meeting the flash, they seldom get, at an average, above one; wherefore, vessels will be frequently from Stock Reach to Leeds or Wakefield, a week or more in making good their passage, that otherwise would be performed in fifteen hours. Hence, there is a necessity of a greater number of vessels being employed upon the river than would otherwise be sufficient to do the business, and, in consequence, a great deal of time necessarily rendered vacant to the boatmen, &c.; hence arises a manifest detriment to the public from so great a number of vessels and men lying unemployed, whose hire and wages upon the whole must be made good by the consumers, and hence, complaints of the boatmen, who rather than be perfectly idle, often employ themselves in doing mischief.

It is manifest, that these stoppages, which last in a greater or less degree for several months in the year, must in their own nature produce the necessity of employing a much greater number of boats and men than would otherwise do the business; yet, if a number were employed sufficient to do the business in the flash seasons, there would not be half employ for them the rest of the year; it follows, therefore, that in those seasons, the business done, notwithstanding every effort, will be far short of the demands of the public: hence, great complaints, for want of dispatch, against the rivers, and against the undertakers, and from those who, if they were apprised of the difficulties and disadvantages under which the business must be done, would be surprised how so much is performed in such a way.

The mills also complain of the water in dry seasons being brought down in flashes, that a great part of it runs waste over the dams, and that they are thereby deprived of a regular supply, and are obliged to wait a considerable time to get their ponds filled again; which complaint, though just, I apprehend has originally been brought upon themselves by their drawing down their ponds, which in return suggested the practice to the navigators drawing their ponds in order to fill the others: thus, the mischief by one party's endeavour to draw down, and the other to fill, becomes accumulated, and which, with the present trade upon the river, it seems to me that nothing can remedy but a different mode of navigating.

To propose an adequate remedy for these obstructions and impediments with as little detriment as possible to private property, the proprietors of the navigation applied to me, and of this I shall now endeavour to acquit myself in the best manner I am able. In doing this I shall not take upon me to consider this matter in so extensive a light, as if the navigation had never been made; but, keeping to the present tract and works wherever it can be properly done, I shall content myself with such alterations as appear necessary to procure the essential of a navigation, viz. the means of keeping vessels always afloat, so as to move freely in either direction when in the proper channel of navigation, and when not loaded beyond a proper draught of water.

Having carefully viewed and sounded both rivers from the town of Leeds and Wakefield, to Carlton Ferry, near Snaith, I find, on comparing those soundings, that the rivers are capable (after making such alterations as in any view of improvement seem indispensable) of being made to carry vessels drawing 3 feet 6 inches water in dry seasons, and at other times 4 feet in its ordinary state, which, according to the present sizes of vessels will carry 30 tons, and 45 tons respectively.

Experience teaches us, that one of the greatest impediments to navigation is that of navigating in mill dams, yet, without forming this navigation wholly anew, it is hardly possible to avoid it totally. I, therefore, lay it down, that in order to secure

3 feet 6 inches water in mill dams in dry seasons, that there ought to be made 5 feet at a full head; this will allow the miller to draw off 18 inches, which will give him a very sufficient scope, and yet reserve 3 feet 6 inches to the navigation: this will be consistent with the millers' interest, as mills expend more water as they draw down to do the same business, and few on this river will do any good execution when drawn down this quantity, the more they are drawn down the more time they will take to fill, so that what is more than the scope above mentioned, cannot in my opinion be considered in any other light, than as means of hurting the navigation; and if it can possibly be supposed (which I cannot suppose), that any advantage can arise from drawing lower than 18 inches within head, yet this will be compensated ten-fold, by saving all the water now expended in flashing, which I look upon to be far more than what is consumed in the necessary and proper lockage of the vessels. Drawing, therefore, the line here, as perfectly reasonable, in order to prevent disputes with the millers, that the navigators be at liberty to diminish the depth of the river in some proper place, between the head of the navigation cut and the mill dam respectively, so as to form an artificial shoal, the top of which, in the lowest part, not to be less than 2 feet beneath the water's surface at a full head.

ALTERATIONS PROPOSED.

Beginning, therefore, at Leeds, I propose the following principal alterations. Just below the warehouse a shoal will require to be dredged, and another formed below the head of the cut: the cut above the lock to be dug deeper, so as to make 5 feet water at a full dam, as far as the elbow; and all the thresholds being considerably too high, the lock must be rebuilt; and as the tail-cut and river below are too shallow, and the deepening both is expensive and uncertain, I propose to extend the cut, and place the new lock lower down, which will drop the vessels into deep water; the river then holds good, or may be made so, with a little help, to Hunslett mill.

Hunslett mill lock, New mill lock, and Twaite mill lock, lie all too high, and at all events, conformably to what is above stated, must be rebuilt; the cuts are all too shallow, both above and below, as well as intermediate shoals in the open river; and as the ponds are short, and thereby the mills can the more readily draw them down, this space is subject to every species of embarrassment, to avoid which, I propose to take a cut out of the river a little above Hunslett mill, and, forming a shoal (as before mentioned), to cross a corner of the Breaks, to cross a close of Sir WILLIAM MILNER's, another of Mr. COOKSON's, Sir WILLIAM MILNER's again, and lastly through a pasture of the Right Honourable Lord IRWIN's, commonly called CLARK's pasture, skirting the high ground, and then falling into the river; this cut will scarcely be a mile in the whole, and will pass all the three mills at once. Flood-gates will be necessary at the head, to keep the floods out of the cut; two locks will be sufficient, with bridges and tunnels, to communicate with the roads and watercourses, the hawling tract being upon one of the banks may be fenced off, if thought necessary.

There are three shoals between the elbow and the tail of the present cut; as they are rocky scalps they may be taken up without interrupting the present navigation; or, to avoid them, the cut may be extended about 150 yards, so as to fall into the river opposite the present lock.

Ryder shoal will need a little clearing; as, also, one below Mr. FENTON's staith: the dam boards will be necessary, as at present, in dry seasons, but may be made to strike at any time of flood, with far more ease than at present.

Cryer cut will want a little deepening towards the head, and the north bank making good.

Woodlesford lock,—its bottom lies too high by about 2½ feet; but, the river being embarrassed with shoals below it, the laying it deeper would be to no purpose; it will be necessary, therefore, either to build an intermediate dam and lock above Swillington bridge, or to continue Cryer's cut till it can be dropped into deep water above Swillignton bridge; the latter, as it will leave the river free from additional dams, is in many respects to be preferred; but, as it would occasion the cut to cross the broad flat part of the valley, and to join the river where there is little flat ground on the opposite side, the water would in time of great floods become too much confined. What I think the most eligible is to continue Cryer's cut along the face of the high ground below the housing of Woodlesford, and crossing the road (from Wakefield to Swillington bridge), to carry it along the skirt of the high ground of Woodlesford field to the Oak Tree close, then to cross to the point of high ground belonging to Mr. BLADES, and from thence to the tail of the cut of Fleet Mill lock, by which the shoals at Woodlesford, and the draft of Fleet Mill will be avoided together. This new cut will be nearly a mile, and to be furnished with proper bridges and tunnels.

Mithley lock bottom is, also, too high, and there being shoals all the way down, almost to Sir WILLIAM LOWTHER's staith, that cut to be lengthened, and a new lock and flood-gates at the head.

From hence to Castleford, good water, with present dam boards there; but, if any alteration should take place, the navigation should have power to build a new dam below the joining of the two rivers, in order to keep the water to its present height up them both.

The bottom of Castleford lock lies too high by 2 feet 9 inches, and the river below is greatly embarrassed with shoals both above bridge and below, insomuch that, in the present state of things, vessels could not pass Castleford without flashes, even if Knottingley dam were always kept full; those embarrassments will be all avoided together by a cut from the mouth of the two rivers across Castleford Ings to the elbow below Castleford, being a little more than a ¼ of a mile in length, with a new lock, road bridge, and flood-gates at the head.

From hence the river continues very good till a little below the tail of Brotherton weirs, where there is a shoal having but 4 feet 2 inches water, and one below Ferry bridge, which has only 3 feet 11 inches, with a full pond at Knottingley, so that with the great number of mill cloughs and waste cloughs upon this head of water, it can, in all common seasons, be reduced so as to lay the loaded vessels aground upon the shoals last mentioned. But this is not all, for even though Knottingley mill were always to keep a full head, the river, for about a mile below Knottingley lock, is so greatly embarrassed with shoals, that with a full pond at Beal dam (the next below), there will not be above a foot of water in some parts of this space, and for the greatest part of that space not 2 feet, and at a medium, about 18 inches; and so great is the tendency of the river to silt and form obstructions in this part, that though weirs for the whole length have been maintained for a long course of years at a very considerable expense, yet this part of the river seems to be in a state of growing rather worse than better; and even if it were, at a great expense, to be dug deeper, so great a quantity of loose sand is lodged by the floods, that there is no answering that it would not choke up almost as fast as it can be deepened. The expedient for passing these shoals has been by putting boards upon Beal's dam, in two heights, so as to raise the water 2 feet above the dam's crown; and as those boards cannot be so easily disengaged in two heights as in one, they have frequently been obliged to remain during the course of flood, which has produced complaints from the land owners in regard to the overflowing of their lands, and from the proprietor of Knottingley mill,

in regard to its being sooner put into back water: the only certain and adequate remedy, therefore, that I see, is to form a new cut by all those obstructions, from deep water to deep water, which will be done by departing from the river a little below Brotherton weirs, and from hence pursuing the general boundary of the north side of Brotherton marsh, and falling into the river into the bend below Anfleet drain, from whence the river is very good to Beal, especially with one height of boards, which may be made to strike as before mentioned, in any time of flood, or it will do without the boards, by taking a cut out of the river, just below the bridge-house, and joining it to the elbow of the present cut above the lock; but I prefer the former expedient, as in this case the more easy, and because it will also retain more water at Knottingley weir.

The cut through Brotherton marsh to have flood-gates at the head, or joined to the great road-bridge for conveying the north road over the cut, a road-bridge answerable to Sutton-lane, and tunnels for the drainage water of the Anfleet. A shoal two feet under dam's height, below the head of the cut, will be wanted to retain navigable water from Castleford; and by way of communicating the navigation to Ferry-bridge, Knottingley mills, &c. a side cut will be required by the said shoal, with a pair of provisional stop-gates, to be shut only in case of the water above being reduced till it is penned by the shoal.

In order to prevent too much confinement to the water in high floods, I propose that for sixty yards, near the bottom of the marsh, the banks of the cut to be laid low and secured, so that the water may find a passage there as at present.

The lock of Beal is almost the only one upon the river Aire that lies deep enough, and from thence to Haddlesey there is good water, with one height of boards at Haddlesey dam, which may be made to strike as the rest do; at present two sets of dam boards (as on Beal dam) are frequently found useful for penning a greater pond of water to produce flashes below.

The open river below Haddlesey lock, for nearly three-quarters of a mile, is embarrassed with continual shoals, which again occur at the Hurst, and where, notwithstanding the weirs constructed for that purpose, the water is not better, for being the place whereabouts the neap tides generally terminate, the warp constantly fluctuating in the tide's way, has a tendency to settle in this place, and, consequently, in dry seasons, the bottom is the highest, when it is most wanted to be low. These obstructions are within the limits of the present act of parliament; but the shoal at Stock reach, about a mile below Weeland, being without the limits of the present act, admits of no palliation; but, as it has nearly the same water upon it at high-water as the shoals above, it has no other ill effect than increasing the number of places where the vessels are subject to be stopped: but, however, as by this means a tide is frequently lost, it certainly, even in the present state of the navigation, is a considerable object.

The most obvious way of curing these shoals is by building a lock and dam at, or below, the Stock reach, so as to pen a sufficiency of water over them altogether; but, besides that dams should always be avoided where they reasonably can be, there is in this place this objection, that as the spring tides would flow several feet over the dam, and bring with them a great quantity of warp, it must be expected to subside in the still water made by this dam, so as probably to increase the present or produce new shallows, as bad as those intended to be cured; besides, as in the present state of the river, there are shallows still below, particularly at the top of Snaith's marsh, and Carleton ferry, where there is but just a sufficiency of water at neap tides, it is no ways certain that the stopping of the neap tides more early than

usual by the new dam above, may contribute to the raising those shoals still higher, and thereby to create new obstructions, which, in the present settled state of the river, is not to be expected.

What I therefore propose is, to take a cut or canal out of the river, just above the present lock of Haddlesey, and, crossing a small part of Haddlesey marsh, to fall in with the hedge of Longcroft, and, crossing Egbar Lees, the old Eye, and boggy ground below Sherwood, to make towards the high ground, opposite to Tranmore house, and there skirting the border of the high ground near the arable fields and marshes to go on to Hensall common, and keeping nearly the direction of the sea bank (on the marsh side of it) till we get to Gowdale marshes and the Intake, and pursuing that boundary nearly, to fall into the river a little above Gowdale lodge clough, where the river being deep, the vessels can be made to lock out and in at low-water, and lie ready to save their tide over the shoald at Snaith's marsh and Carleton ferry, over which shoals, according to my observations and information, vessels loaded as before mentioned, are always secure of a passage at high-water.

In the cut before mentioned, a large tunnel will be required for the passage of the water of the old Eye under the canal at Egbar Lees, and to give the usual passage to the water in high floods and breach of banks from above, I propose the banks of the canal near the old Eye to be made low for 100 yards (and to be secured), that the back flood water may go over them, with stop gates at the high grounds, to prevent the floods from making their way down the cut, and also at the head, to prevent the river from flowing in till it goes over the marsh banks, &c., stop gates also to be placed at the cross bank between Hensall marsh and Heck Ings, and likewise between Heck Ings and Gowdale Intake; the following tunnels will be wanted for communicating drainages, viz. Haddlesey marsh, Hensall drain, Heck Ing clough, and Gowdale marsh; proper bridges will also be placed to join the roads and communications to grounds; the principal will be to Haddlesey marsh, Sherwood road, to the Ings, Egbar ditto, Hensall ditto, Hensall road to Weeland, Heck Lane to the Ings, and from Gowdale marsh to the Intake.

I have also examined the grounds on the north side of the river, and find a cut equally practicable there, and, in some respects, preferable; but, being wholly through inclosed farms, I have caused the first survey to be made as above described, which will pass chiefly through the open Ings and marshes, and for the greatest part through grounds of very little value, being the separation between high grounds and the low; the whole length will be about three miles and three-quarters.

Though I do not see an absolute necessity of extending the cut below Gowdale lodge clough, in order to procure the essentials of a navigation; yet, as obstructions at present unforeseen may arise, it seems to me necessary that the undertakers should have a power of removing obstructions, and making horse towing-paths from the outfall of the river Aire into Ouse, to Gowdale lodge clough, as well as above.

Having now despatched what seems most necessary respecting the river Aire, it remains to make the requisite observations upon the river Calder.

The most embarrassed part of this river, and the only one dependent on mills, is the cut from the warehouse to the lock. Were the mill at the tail of this cut to keep always a full head, there would need little alteration, but as this is scarcely to be expected, the most practicable expedient is to dig the cut eighteen inches deeper, and to form a barrier as before mentioned, so that the mill cannot draw above eighteen inches within head. This, however, will not be perfect, as the withholding the water at the Soak mills at Wakefield, from whence alone this cut is supplied, will occasionally and temporarily stop the passage of this cut. The navigation, therefore,

in order to make it complete to Wakefield, should have a power either of filling the cut from Wakefield mill dam, or to purchase ground to make warehouses near the tail thereof, with a road to lead to them.

The dam boards at Castleford being preserved as at present, the whole pond from Penbank lock to the river Aire will have a sufficiency of water, a place called the Meer Round excepted, with some little places that may easily be helped near the tail of Penbank: the bottom of Penbank lock, however, lies too high by nearly a foot, and, as it must therefore be rebuilt, the proprietors should have it in their power to rebuild it in a new place and lengthen the cut, so as to drop it into deep water about 100 yards lower, or to rebuild it in its present situation, as may ultimately appear most advisable.

The dam boards of eleven inches being preserved and made to strike with ease, at Kirkthorpe Lake and Penbank dams, will make the necessary water from Wakefield lock to Penbank, except one shoal, called Holford, about a quarter of a mile below Kirkthorpe lock, which, being a rocky scalp, I advise to be lowered by hand labour, rather than make any lengthenings in the cut of Kirkthorpe.

The Meer Round is a sandy shoal of no great extent: it is probable it may be helped by proper weirs, without making any new cuts, and hence we pass into the river Aire without further obstructions.

It is necessary to mention, that for the sake of preserving the course of the present navigation from Knottingley townside upwards, it will be proper to keep Knottingley lock in repair; and also, for the sake of preserving the communication of Mr. Brandling's coal staith, it will be necessary to keep the Thwaite lock in repair; and in general, where there is no particular objection, I would advise, that all the present locks be kept up, as by this means, when any thing happens amiss with one lock, where there is a duplicate, the navigation can be carried on by the other while it is thoroughly and substantially repaired, nor will the mills lose any thing by a double leakage, as it will be very easy to keep the locks, where there are duplicates, in far better order than is practicable in the present state of business.

Austhorpe, 28th December, 1771. J. SMEATON.

THE REPORT

Of John Smeaton, Engineer, upon a View of the Calder Navigation, the 25th and 26th Feb. 1779, in Company with Messrs. Royd, Charlesworth, and Waterhouse, of the Committee, and Mr. Walpole, Agent.

Respecting matters of common repair, those having been pointed out on our passage up the river, I shall at present confine myself to such things as tend to improve the navigation, by removing those obstacles that length of time and experience have pointed out after successive repeated floods, of which the following seem to occasion the most frequent stoppages, and the most frequently need temporary helps.

1st. Horbury mill pasture cut head, now called the Broad cut head.
2d. The Long cut head, at Dewsbury.
3d. Batty's mill cut, tail and head.
4th. Kirklee's cut, head and dam.
5th. Tail of Anchorpit lock.
6th. Brighouse cut head and dam.

I.—BROAD CUT HEAD.

The head of this cut, from the gradual wearing away of the land by floods, has always been very subject to sand, therefore often required to be raked, and become very troublesome; there was once a rubble weir thrown in from the up-stream point, which seemed to answer very well, till the succeeding floods took away the land, leaving the weir disjoined, which then coming in the way of vessels, has been totally removed. The only complete remedy will be to make the entry from the cut from the deep water higher up; and, as it appears from observations upon the whole river, that those cut heads preserve themselves best from sanding, whose upper point of land projects further into the stream of the river, than the lower point, this cut would best commence from the ground above broken by the floods making the projecting point, the upper side of the cut's entry, and this being preserved as it is, by being footed with rubble, the annexed sketch, plate 38, fig. 1, will give an idea of the alteration; it will be proper to leave a space between the south bank and the foot of the high land, otherwise all the flood-water will be stopped from going that way: and to prevent the flood-water from going in at the new entry, and out again at the old one, and thereby hawling in sand and silt, it will be proper to put stop-gates upon the new cut head at A; and lastly, as this new cut and works will be dug and founded below the level of the water of Horbury mill-dam, with the water of which and Broad cut it will be in a great measure surrounded; therefore, unless a trench can be cut eastwards, under the high ground on the south, these works must be bottomed by artificial drainage, which, as it will be in an open gravel, will be very expensive. If, therefore, the execution of this scheme should be thought too expensive, I would propose, for trial, that contained in sketch, fig. 2, where, to prevent the lands going away any further, and thereby widening and filling up the river, I would begin to foot it up from the broken ground above, with a slope of rubble; and, lastly, carry out its lower end into the stream as is shewn at B, in the sketch, fig. 2, which, being raised but a little above the common surface of the water, will, as far as it reaches, in time of freshes and floods, act as a dam, and instead of a sand in its eddy, will make a deep, and thereby keep a channel open, and, being carried out to a sufficient distance, what matter goes round its end will be carried down the stream without being deposited, as it is now, upon the eddy shore. Doubtless this will make the entrance more awkward, but any thing is better to a vessel than being catched by the bottom, and particularly in the dam of a mill, or to need being raked off after every flood and fresh: the original weir or jetty was constructed on this principle, but the ground not being footed up and secured for a length above it, it was washed away since my attendance, and the place left as before mentioned.

II.—THE LONG CUT HEAD.

This cut head needs frequent raking, and is more troublesome than it should be, though it opens into the navigation's own pen of water. I do not find that internally it is attended with much trouble, and as the down-stream point of the entry projects further out than the up-stream, I would recommend to try the effect of cutting and rounding off as much of the down-stream point, as can be done with safety, facing up the lower part of the new dug surface with rubble, to prevent the action of the floods upon a new surface, from taking away what may be prejudicial; and if the simply taking away from the down-stream point should not be sufficient, it may be further helped by being rendered more prominent by a rubble jetty from the up-stream point,

somewhat in the nature of that proposed for Broad cut head. If nothing of this kind should fully answer, an effectual cure can be made by a new cut following the skirt of the high land under Mr. WILCOCK's house, and coming into the river a little higher than the opposite point of watergate lock; but, as the navigation cannot now be stopped, the digging of the cut under level of the natural drainage, the necessity of a very stout pair of flood-gates at the head, or rather a flood-lock, are considerations that in my opinion render it advisable to try what effect will follow from the more simple methods above pointed out.

III.—BATTY'S MILL CUT TAIL AND HEAD.

In regard to the tail, which was sanded on this view, and is now liable to sand, it wants nothing but a low rubble weir or jetty from the up-stream point of the tail of the cut, exactly like that at Wakefield, which was constructed by my directions, and the cut's tail has never sanded since. It is very possible that the sharpness of the up-stream point of Batty's tail might for years be preserved by a bush or root, a few rubble stones, or other accidental matter, which being now worn and taken away, may render it more liable to sand. A good deal of the upper part of this cut is rather shallow, but as what is below the upper gates may always be cleared at pleasure by drawing off the water, I shall not dwell upon it. The principal grievance is a great tendency of this cut's head to sand, so that it needs often raking, and seldom continues long quite free. This cut going both by Batty's and Hall's mill, its head opens into Hall mill-dam, and as this dam continues good when vessels are fairly into it quite away to Cooper's bridge lock, with a good entry there, and as a new cut cannot be taken upwards to much more advantage, without being carried through ground to a considerable height, and where a new pair of stout flood-gates will be wanted, I would advise to attempt to remedy this entry, in a way somewhat similar to that proposed for the Broad cut head; because, exclusive of this single circumstance of its great tendency to sand, the rest can scarcely be better.

The sketch, fig. 3, which is merely done from memory, is supposed to represent the cut head, as it appeared sanded upon this view, and in the narrow of which there was but barely three feet water at dam's height, though every other part was unexceptionable. In order to remedy this, I propose to cut a new entry, pointed square to the stream as shewn in sketch, fig. 4, its up-stream side and point defended by a rubble jetty, raised but a little above dam's height, that the water may fall over it, and which upon the same principle as laid down respecting the jetty or weir for the Broad cut head, instead of a sand on its down-stream side, will produce a deep, and by projecting it a little into the river, will also produce a deep round its termination, and thereby continue a deep passage from the cut to the river. This again will, doubtless, render the entry more awkward; but the very best in every respect, and the cheapest are not always compatible in an artificial inland navigation. However, to render the entry more safe, in time of freshes, when alone in reality there can be any difficulty, I would advise a couple or three strong piles to be driven in the course of the river, as shewn in the sketch at *a a*, and that a very strong mooring-post be fixed upon the land at A, by which vessels may be lowered gradually down the stream, and by a cross rope from the vessel's head, swung into the cut before they quit their hold at A, and if, in going up in a fresh, they get fast to A before they go out, their getting out will be perfectly easy and safe, though there were to be no piles in the river at all.

IV.—KIRKLEES CUT HEAD AND DAM, AND V.—THE TAIL OF ANCHORPIT LOCK.

If Kirklees cut head were the only defective part, it would be worth while to try a remedy upon the same principles as the last, but as the dam itself is too shallow in several places, which have grown worse rather than better of late years, in consequence of which frequent stoppages happen that require the reach above to be drawn down, which, of course, produces a loss of time and hindrance there, to wait for its filling; and as the tail of Anchorpit lock, though very good formerly, has become much obstructed by stones, &c., being brought down from the tail of the dam, and therein deposited; to remedy all these evils at once, I would propose to take a new cut out of the Anchorpit dam on the south side, and, following the verge of the high ground, to carry the level of Anchorpit's dam water along, till near the flood-gates of Kirklee's cut, and there, by a new lock, to drop the vessels into Kirklee's cut, just below the present flood-gates; by this means the navigation by those mills will be rendered independent of them; a circumstance, I believe, very desirable to all parties.

A pair of flood-gates will, doubtless, be required at the entry from the river into the new cut; but, the land at this entry being bold, the placing of flood-gates will be very convenient; and as the whole will be dug and founded (the lock-pit excepted) above the level of Kirklee's cut water, the expense will not be enhanced by artificial drainage, for the work being bottomed from the tail towards the head, the water will be drained by the cut, and nothing of the present passage disturbed till the new one is opened.

VI.—BRIGHOUSE CUT HEAD AND DAM.

Since the flood-gates near the head of this cut were erected, that part of the cut across the low meadows from the flood-gates to the river, has become very subject to sand, which, being of some length, has become too troublesome. The river has also become more shallow between this cut head and Lilland's lock tail since the breaches at Lilland's. Those evils will admit of a complete remedy only one way that I can see, and that is, to carry the cut from the present flood-gates up the meadows, to a point nearly opposite to Lilland's lock tail, and to secure the water there by a catch dam, which will also render the navigation by Brighouse independent of the mills, which is indeed very desirable.

Flood-gates at the head will certainly be needed, and the digging of the cut will require artificial drainage; but as the cut will be shallow, and I have hopes that the soil will not produce much water, and that this may be done at a moderate expense, as no new lock will be required; and by these means the navigation will be rendered independent of all the mills from Cooper's bridge lock to the head.

Above Lilland's, nothing of moment occurs till we leave the river at Brook's mouth, and there the double lock is a very great evil, on account of its great consumption of water, at a place where it is most scarce, but as no alteration in it can take place for the present year, I shall reserve my opinion upon the particular mode of remedy, till a further opportunity, only intimating that the double lock should be converted into three single and detached locks, of which I expect that the uppermost may be converted so as to make one.

The runs in the Sowerby bridge cut should certainly be stopped the ensuing season. The mode of which being sufficiently pointed out and understood upon this view, it need not enter into this Report.

LONDON, 22d March, 1779. J. SMEATON.

RIVER AIRE DRAINAGE.

The Report of JOHN SMEATON, *Engineer, upon the Drainage of certain Low Grounds lying upon the River Aire, in the Parish of Kildwick, from a View thereof, taken* 31*st May and* 1*st of June,* 1764.

THE river Aire seems, in general, to run very dead, and in a remarkably meandering course in the neighbourhood of Kildwick, so that the lands lying thereupon are much liable to floods in the winter season; but the lands which were the immediate object of this view were many of them under water at the time of taking it, and the rest were so spoiled by the long continuance of the water upon them, that their value is greatly diminished, and all further improvements rendered difficult and precarious, without immediate help from drainage. I have also been informed, and my own observation agrees therewith, that these lands are now in a much worse state, with respect to drainage, than they formerly were; insomuch that several parts are now below the level of the surface of the adjacent river, into which they drain (when in its ordinary state), that formerly were above it, and then were firm and dry land. The evident cause of which alteration is as follows: On the south side of the river Aire comes in a beck, which, rising more immediately from among the hills, in rainy seasons comes down with great rapidity, and, in its course, washing the foot of certain cliffs, or beds of pebbles, gravel, and shingle, brings with it a great quantity thereof at such times, which matter being disturbed or moved by art, for the sake of washing or collecting such pebbles as are of the lime-stone kind, for the purpose of making lime, about two miles above the mouth of this beck, as I am informed, must of course greatly contribute to increase the quantity that otherwise would be brought down its course: the quantity of this matter already brought down is so great as to have, in a manner, filled up its own channel, so that for nearly a mile in crossing the plain, from the hills to the river, its bed is in general higher than the adjacent lands, the waters being confined between artificial banks; but these banks having been raised only occasionally, and by piecemeal, as the bed of the beck has grown higher, are in general too weak and slight to confine the waters in time of high floods, so that the surface of the adjacent lands is covered with pebbles and gravel in many places, where it has been driven through the branches.

The channel of the river Aire is in this neighbourhood naturally deep; but the great quantity of gravelly matter, brought down by the beck above mentioned in the channel of the river, being carried downwards by the violence of the floods of the Aire, in rainy seasons, has in a great manner filled up, or obstructed the channel of the river for half a mile below the mouth of the beck; and it has been remarked, and, in my opinion, such an effect must naturally follow from such a cause, that the shingle above mentioned travels every winter lower and lower in the river, as the quantity brought in increases; and, at the same time, near the mouth of the beck grows higher and higher; so that it raises the water in the river above these obstructions, in the manner of a dam, and at present pens it over the surface of several of the lands, to the great detriment of others with which it is almost on a level; and as this evil has come on gradually increasing, it is probable that the surface of the river has gradually risen several feet within the compass of a moderate number of years, as is confirmed by persons now living; and, therefore, if some method be not taken for remedy thereof, in all probability it will grow to such a pitch as to render useless all the low grounds upon the river Aire between the said beck and Coningley mill,

unless the river should force itself a new course through the meadows below, as it probably will do (such instances being frequent) unless timely relieved by art.

As the effect of the aforesaid obstructions is to pen up the water of the river above the same in the manner of a mill-dam, which reaches nearly upon a dead level as far as Coningley mill, which I compute to be about three miles, by the course of the river, the meadows on both sides, lying low, are immediately put under water by a small rise of the river by rain. The meadow in going up the river towards Coningley mill gradually rises higher and higher above the surface of the river, as it was in the dry season, when I viewed it; yet, as these lands lie further from the out-fall of their water, the water advances upon them in proportion to their distance, when it is raised by a flood, so as to make them equally liable to floods, though not of so long a continuance. The land lying on the south side of the river, between the aforesaid beck and Kildwick bridge, and for about a mile above the said bridge in the same side, seems most oppressed with water. On the north side, between the bridge and Coningley mill, something has been attempted by way of banking; but as a great part of the embanked land was not at the time of this view above a foot higher than the surface of the river, and a good deal only a few inches, it follows, that, though these banks may be of use in keeping out sudden and casual floods from spoiling their crop in summer, yet the continued floods in winter, as there will be no passage for the waters from the surface of the lands into the river through the tunnels, the river being then generally for a long time together higher than the surface of the lands, there can be no drainage, and, consequently, the banks will be of little use, as the land will be starved and impoverished by the continuance of the downfall and soakage water upon them; and as the quantity of shingle keeps increasing, and the surface of the river will be raised higher and higher, it is very probable, that, in the course of a few years, the surface of the river will be higher than the surface of a great part of the said embanked land, in which case the partial drainage which they now enjoy will cease even in summer.

For a general remedy of the drainage of all the low lands that adjoin the river Aire on both sides, between the said beck and Coningley mill, I would recommend the making a new cut or river from that part of the river stagnated by the said obstruction to a convenient part below them, by which means several feet of water may be drawn off from the said stagnated pool, and thereby the river, as well as the lands dependent hereupon, be put into their ancient course of drainage and improvement.

Having carefully viewed the course of the river from the commencement of the obstructions to the termination thereof, being in length about half a mile, there appears to me by estimation to be at least six if not eight or nine feet of fall. I did not take a level, because the time previous to the meeting of the gentlemen concerned would not allow it; but as there is an ample sufficiency of fall for the purpose, it is of less consequence what the level exactly is. Now, it is evident, if there be six or even five feet of fall, that by a sufficient cut the water will be drawn off five or at least four feet below its present surface; and, as the channel is in general six or seven feet deep above the obstructions, the water will reduce itself, in dry seasons, a proportionable quantity all the way as far as it pens upwards, that is near to Coningley mill, and, consequently, take off the surface waters from all the adjoining lands, as before asserted.

This cut I would not advise to be at a medium of less dimensions than as follows, viz. twenty feet bottom, forty-five feet top, and eight feet deep.

The proper place seems to me to be on the north side of the river, from or near

the head of Mr. RICHARDSON's corn farm, thence almost straight through the low end of his grass, turn thence through Mr. BALDWIN's Garforth Ing, and thence through Mr. BALDWIN's Holme, into the present course of the river, where grows a pretty remarkable clump of ash trees. This course being measured, was, in length, three furlongs and twenty-three yards. A cut of the above dimensions, at 3*d.* per yard cubic, will come to 79*l.* 9*s.* 6*d.* per furlong, and for three furlongs twenty-three yards, 246*l.* 14*s.* 8*d.* The land cut will be two roods twenty-nine perches per furlong, and therefore in the whole, two acres and eight perches. The land covered on each side will be nearly equal to the cut, which being supposed of half value, the damages to be paid for the cover will be equal to the value of the land for the cut. One bridge over the same will be wanted, which, if built of stone, may probably cost about 80*l.*

A cut of the above dimensions will vent as must water as the old river, when the flood rises even with the grass; but were it of ever so great dimensions, it cannot vent the water faster than it comes.

The old river I would advise to be kept open, as a receptacle for the shingle coming down from the beck: and as the old river will be less loaded with water in time of floods, it will afford a readier passage for the water of the beck; and the force of the current being less violent in the old river, will not drive down the shingle so fast into the river below the tail of the new cut. Hence I disapprove of cutting for the beck a new course into the river to a lower point; because, by giving it too much fall, it will bring down shingle the faster, and, by carrying it in at a lower point, the shingle so brought will sooner get down the river into the part now unobstructed; to do this would, therefore, be to destroy the whole for the sake of a part.

In case the scheme above proposed should meet with difficulty, a drainage from the lands in question may be obtained by bringing up a back drain from or near the point above specified, between the river and the high land, and banking against the river. This may be done on both sides the river; in which case the drainage on the south side must be carried underneath the beck by a sunken funnel or fox. This method may be practised with great convenience as far as the bridge; but yet is not obliged to terminate there, but may be carried forward through the low grounds on both sides, as far as necessary, towards Coningley mill. As it would greatly add to the expense to raise the banks sufficiently high to keep out the great winter's floods, and at the same time, as I apprehend, impoverish the lands for want thereof, I would advise not to raise the banks more than four feet above the low-water's surface, laying them, where made new, very flat and sloping, and well sodded, that the water, in going over them, might not make a breach.

Something might be done by way of clearing the old river; but to be in any degree effectual, must be at a much greater expense. The parts most requiring clearing, are those near the head of the shoal, that is, near the mouth of the beck, which, of consequence, would be again the first filled up. Upon this scheme it would, therefore, be advisable to turn the beck to the tail of the shoal, because there is most room for the deposition of its contents, without immediately obstructing the parts supposed to be cleared; but as this would in consequence produce an obstruction still more extensive, a radical cure will be rendered still more difficult and expensive.

AUSTHORPE, 26th July, 1764. J. SMEATON.

P.S. For the evils arising to the lands from the flooding of the beck, I see no lasting remedy; they arise not for want of fall, but rather by hewing too much, so

that let whatever course be made for it, it will be liable to be choked with gravel, unless the coming down of the gravel could be prevented; if this can be done only by enlarging its channel, and affording it room for the deposition of its contents, it may be effected by raising and strengthening its banks, partly with the matter lodged therein, and faced up next the channel with new earth from behind to give it room, by raising a fresh bank parallel with its eastern one, at forty or fifty feet distance, taking the matter from between the banks to make the new one, which will, in some measure, make a new channel, letting the beck have both the old and new course to range in time of floods.

RIVER AIRE CANAL.

The Report of JOHN SMEATON, *Engineer, upon the Plan and Projection of a Canal on the North Side of the River Aire, from Haddlesey to a place called Brier Lane End, in the Township of Newlands, as laid down by Mr.* JESSOP, *Engineer.*

IN my Report of the 29th Dec. 1771, upon the improvements of the navigation of the rivers Aire and Calder, from the towns of Leeds and Wakefield, to the free and open tide's way, after setting forth the practicability and utility of a canal to be made on the south side of the river Aire, from Haddlesey to Gowdale Lodge Clough, and that it would be the means of making a communication free and open at high-water in the shortest tides and driest seasons, between the upper parts of the river and the lower, without the use of flashes,—I further mentioned, that having also examined the grounds on the north side of the river, I had found that a cut on that side would be equally practicable, and in some respects preferable, to that on the south, but which was not further pursued at that time, for the reasons therein set forth. The application to parliament being postponed to another session, having given an opportunity to the proprietors of the rivers Aire and Calder further to consider the utility that a canal on the north side of the river would be to them, and how the ground on that side would be affected thereby, they again applied to me for that purpose; but being myself altogether otherwise engaged the past summer, I recommended Mr. JESSOP to make the necessary surveys, plans, and projection, which being produced, at the further request of the said proprietors, I have taken a view of the line of the canal, as proposed by Mr. JESSOP, and, having also examined his plan, report, and estimate, I am of opinion, with Mr. JESSOP, as follows:

1st. That, by extending a canal from Haddlesey dam-head to the river Aire, at or near a place called Brier Lane End, in the township of Newlands, being in length about $7\frac{1}{4}$ miles, the communication between the upper part of the river and Armin, will not only be shortened considerably more than by a passage from the said dam to Gowdale Lodge Clough, before proposed on the south side, but will be attended with this further great convenience to trade: that, whereas by the Gowdale canal there would, in dry seasons and short tides, be a navigable communication only at high-water; by the present plan, there will be a navigable communication between the upper parts of the river and Armin, at all times, except at low-water in dry seasons, which would very often be a saving of twelve hours in the passage.

2dly. That, by raising the south bank of the canal so as to be flood proof, all the great tract of low grounds, lying to the north of the canal, will be entirely embanked

and defended from the floods of the river Aire, arising from breach of banks in that long tract of river between Haddlesey and Brier Lane End, being by the course of the river at least 12½ miles; and that, though the water being confined upon the lands on the south side of the canal may, in some smaller over-flowings, increase to a greater depth; yet, in the great overflowings of the river, as the water can never rise higher upon the lands than the water in that part of the river from whence it proceeds, there then can be no great difference; and in all cases, as there will be a less extensive body of water to be discharged, it will be much sooner discharged by its out-falls, which, in drainage, is of the greatest importance, as the waters standing long upon the grounds do more damage than can arise merely from the depth of it.

3dly. That the drainage of the whole country neighbouring upon the canal will be greatly mended; for, as the surface of the canal will not be liable to rise and fall like the river, being defended by gates at each end, all these grounds that lie higher than the surface of the canal will drain immediately into the canal, and all those grounds whose surface lies even with or below the level of the canal, will drain into the back drains that must, of necessity, be cut behind the banks, which, by conducting the water from the surface of the adjacent country, by the most ready passage, to the main drains of the respective out-falls, will be a great means of improving the present drainage; and, as there will be capacious tunnels under the canal, where it intersects such drains, with stop-doors upon the tunnels to prevent the waters reverting where necessary, this advantage will operate equally on either side.

4thly. That the above means will put the drainage upon a better footing than it is at present, which is sufficient for a scheme of navigation; yet, as the canal is proposed to be embanked flood proof on both sides, between Newland's bank and the out-fall at Brier Lane End, the drainage of Carlton might be improved by running off a part of their top waters by a sluice into this part of the canal, and yet Newland's fully defended by the said stop-gates proposed at Newland's bank, and which, at any rate, will be a proper security.

Upon the whole, I see no objection to this design of Mr. Jessop's, but what would be made to a canal passing in any line through this country: on the contrary, I think it well adapted to answer the end, and to avoid the severing of properties as much as possible.

Respecting Mr. Jessop's estimate, I beg leave to observe, that the longer I live, I every year see more into the reasons why estimates are generally exceeded in the execution, and how impossible it is, without repeated proofs from experience, to conceive how this can happen in so great a degree; I, therefore, do not wonder, that he has come considerably below the prices in the articles of construction, that I should esteem it necessary, he not having had an opportunity of having recourse to my estimate for the performing of the Gowdale canal, which is similar to this, but which now being put into his hands, he will be enabled to re-model his estimate according to the prices thereof. Indeed, respecting the article of land, I have done nothing more than give the quantity of acres, cut and covered, as I apprehend that no engineer should venture to name a price for it.

Austhorpe, 5th December, 1772. J. SMEATON.

RIVER LEA NAVIGATION.

At a Meeting of the Trustees for the River Lea, at the Bull Inn at Ware, on Wednesday, the 16th day of July, 1766.

PRESENT,

THOMAS DIMSDALE, M.D.	JOHN IVEE GOPP, Esq.
THOMAS PLEEMER BYDE, Esq.	Mr. THOMAS STROLT.
JOHN CALVERT, Esq. M.P. for Hertford.	ABRAHAM HUME, Esq.
JOHN JENKINSON, Esq.	WILLIAM COWPER, Esq.
JOHN ROWLEY, Esq.	SAMUEL ATKINSON, Esq. Mayor of Hertford.
THOMAS WALTON, Esq.	PAUL FIELD, Esq.
TIMOTHY CASWELL, Esq.	RICHARD DICKINSON, Esq.

Ordered, that Mr. JOHN SMEATON shall forthwith take a survey of the river Lea, and make a plan and estimation of the best method of making a navigation from Hertford to the river Thames; and that Mr. THOMAS YEOMAN shall assist him therein; and that Mr. SMEATON make a report thereof to the trustees on or before the twenty-ninth day of September next; and Mr. SMEATON is desired to be as particular as he can in the description of such parts of the course of the said intended navigation, where he shall be of opinion that new cuts ought to be made, and what effect such new cuts will have upon the lands they shall respectively pass through, and the mill and other estates adjacent.

Examined by me,

HENRY THOROWGOOD,

Clerk to the Trustees.

THE REPORT

Of JOHN SMEATON, Engineer, upon the New Making and Completing the Navigation of the River Lea, from the River Thames, through Stanstead and Ware to the Town of Hertford.

THE present navigation of the river Lea, above the tide's way, being, in all probability, formed upon such expedients as occurred before the invention of locks, or pen-sluices, with double pairs of gates, is now, when compared with the modern improvements in navigation, become very defective, notwithstanding many attempts to improve upon its present principle, which is that of pens and flashes from eighteen weirs and turnpikes; besides a cistern or lock properly so called at Ware mill; and the lock at Bromley, improperly so called, having only single gates for penning in the tide, through which the vessels navigate in tide of flood, or about the time of high-water: these, with a cistern or lock occasionally used at Hackney water-works (lately erected), are the present means of navigation through a course of river of more than 31 miles from Bromley lock to Hertford, and having 111 feet fall, or thereabouts, as appears from a survey and level of the river, which seems to have been very well taken near thirty years ago.

In the month of July, 1766, having, with the assistance of Mr. THOMAS YEOMAN, engineer, and by order of the trustees for maintaining and improving the said navigation, carefully taken a view with many observations on the present state of the river and navigation thereof, and having compared the same with the old plan before mentioned, I herewith present the trustees with a new plan of the said river, with three schemes for completing or improving the navigation thereupon. The first containing every improvement that in point of expense I would recommend; the second containing the most frugal scheme that I can recommend; the third is a medium between the two extremes, and which, upon the whole, seems the most eligible. The whole is founded upon these general principles:

1st. To do no damage to the adjacent lands; after the lands required for the works and temporary damages in constructing them are paid for.

2d. To do no damage to the mills by diverting their water; and to preserve to them the several navigations in their own mill-streams that they now have.

3d. As much as possible to prevent the mills from injuring the navigation, by drawing down their ponds.

4th. To make a safe and certain navigation in the dryest seasons with 3 feet water in the general, and at least 2 feet 6 inches in the shoals of the river and fording places made across the cuts.

To execute this scheme I propose

1st. To keep the river where it is tolerably straight, and sufficiently deep, for a length of course together.

2dly. To join those deep cuts and canals with locks thereupon, whereby the vessels will be enabled to pass from one deep to another without any flashes.

3dly. To make use of such of the old weirs or turnpikes as will be necessary for keeping up a constant body of water in the cuts and canals, in no case to pen higher than those weirs or turnpikes do at present; but in general not within four or six inches of the present height, and if it shall appear that any damage is done to the grounds by keeping up the necessary body of water in dry seasons, to embank the river in such places, and make back drains to carry off the soakage water into the pool next below, at all other times, as there will be a sufficiency of natural depth of water, the gates of the weirs and turnpikes to be drawn, in order that the river may have its free passage as at present. N.B. Three or four men that will be necessary to see that no damage is done to the locks and cuts, will also draw the gates as aforesaid.

4th. To navigate by the flow of the tides hitherto, till the barges are past the falling in of Hackney brooks.

ADVANTAGES OF THESE MAXIMS.

From hence the mills will receive great advantage from no water being wasted in flashes, which not only greatly diminish their heads but obstruct them by tail water.

The lands will also be benefitted by not being liable to an uncertain pen of water.

The navigation will be not only improved by being rendered certain at all times, except in frosts and extraordinary floods, and by the shortening the distance, but by navigating in more still water, and in the straighter courses much labour in towing will be saved, and will be rendered so expeditious, that a vessel at moderate work will make her way upwards at the rate of two miles per hour, passing the locks included; that is, from Bow bridge to Hertford in about thirteen hours. Hence the ruin of horses, straining of barges, and great wear and tear of the tackle, will be saved, as well as greater expedition be secured.

The different schemes referred to, with the separate expenses of the divisions thereof, will be sufficiently explained and compared by inspection of the three abstracts, and the particulars of each division will be had by inspecting the two estimates, of the different parts.

It is to be noted, that nothing is to be supposed as proper matter of my estimate, save what is contained in each abstract previous to the double line; the value of lands and weirs is thrown in, in order to make a comparison of the different methods; which will again turn out somewhat different, according to the different values that are put upon them in the opinion of different persons, and that no conclusion may be drawn from the values that I have placed to weirs, turnpikes, and cistern lock at Ware, I have mixed the uncertain value of repairs that will be wanted to each therewith.

As I have endeavoured to settle the land-marks or principal stamina of this undertaking, I am well assured that what remains (which could not be done before), will be properly inquired into and represented by Mr. YEOMAN, that is, if any of the three or any part of the three schemes are thought proper to be carried into execution. It will now be proper that Mr. YEOMAN be employed to look over the grounds where the works relative to such scheme are to be, and as he is a judge thereof, which I am not, to take notice of the probable value; as also how, by any deviations from the lines I have drawn for the cuts and canals, the divisions of properties may, as much as possible, be avoided; and in case any other way than what is pitched upon on the first face of the thing shall seem more proper on re-inspection, to make report thereof, with such other matters as shall be directed, or shall occur to him, by which means the trustees will have the whole matter fully and clearly before them.

I furthermore desire, that what I have set down in the abstracts, under the title of expense of the works, is to be considered as so much hard money, without defalcation on account of the charge of this scheme, the act of parliament, the interest of money, or any salary or gratuities that may be thought necessary to the principal director or directors, or the clerk or clerks of the works.

It perhaps will be wondered why, in my third scheme, I have not preferred the keeping of that part of Enfield mill-stream, contained in the second? My reason is, that as that mill-stream is at present fed by a limited quantity of water, and millers are perpetually over-drawing their supplies, in dry seasons the navigation would frequently be interrupted thereby.

I also entirely reject the new cistern lock at Hackney as part of my scheme, as neither its floor nor the river below is deep enough for navigation, without flashes there, as at present.

On inspection of the plan, it seems very desirable that a cut should be carried from the four mill pond at Bromley to the Thames at Limehouse hole, and which, from a general knowledge of the ground, I believe very practicable; yet, as this thought did not occur to me till I was compiling the plan, I must refer the gentlemen to Mr. YEOMAN's Report thereupon, to whom the same thought has occurred, and who has viewed and levelled the same, and which I shall inspect when I go up to town, if thought eligible.

If the navigation below Bromley is thought proper to be continued through Bow Creek as at present, it will be proper to have a power in the act to lay Bromley lock lower, whenever it shall need a thorough repair, and make it with two pair of gates.

The following estimates are founded upon the suppositions, that the ordinary size of the cuts and canals are a sixteen feet bottom, with batter, as one to one on each side, and to be three feet deep of water, but to allow for passing places, four at least in a mile, making fords and extra depth of ground where it lies considerably higher

than the water; they are calculated upon a mean width of 18 feet bottom, and 4½ feet deep, and to be done at 2½*d.* per cubic yard, drainage of water, where necessary, included; on these principles the cuts will be made for 27*l.* 10*s.* per furlong; and each furlong will, at a chain broad, including banks and back drains, contain one acre per furlong.

The locks to be made fit for the Ware barges at 100*l.* per foot perpendicular, the extra charge of lock pits and drainage of water further included.

I have supposed all the weirs, with the cistern lock, to be private property; all the turnpikes belonging to the navigation; and that Archer's weir must be purchased, in order to be removed; if I have mistaken in that point, my mistake therein can easily be corrected.

Austhorpe, 24th September, 1766. J. SMEATON.

AN ESTIMATE

For making Navigable the River Lea, by such Cuts and Canals as were approved of by the Trustees of the said River upon their Inspection of the same, from Bow Bridge to the present Place of Delivery at Hertford. By John Smeaton, Engineer.

FROM BOW BRIDGE TO LEA BRIDGE, INCLUSIVE.

	£.	s.	d.
To clearing a shoal just above Bow bridge, called Bow Bridge Hill	150	0	0
To clearing two fords below Old Ford dock	50	0	0
To two miles of canal, which, at 3*d.* per yard, and with the dimensions specified in Mr. Smeaton's Report, comes to 33*l.* per furlong, and for two miles	528	0	0
To two locks penning 4 1 each	820	0	0
To two tail bridges to ditto	30	0	0
To bridge and flood-gates at the head of the cut	120	0	0
To making five fords for communication across the canal, which, including bridges, is at the rate of four passages per mile, at 10*l.* each	40	0	0
	* £.1688	0	0

To be purchased for this work, land sixteen acres.

FROM LEA BRIDGE TO NEWMAN'S WEIR, INCLUSIVE.

To cutting two loops of the river Lea, between Lea bridge and Hildyard's turnpike	30	0	0
To five miles and a half of canal, exclusive of Enfield mill-stream, at 33*l.* per furlong	1452	0	0
To scowering Enfield mill-stream, with contingents thereon	330	0	0
To lockage upon this canal 33 4 perpendicular	3333	0	0
To seven tail bridges, at 15*l.* each	105	0	0
To a road bridge, answerable to Hildyard's turnpike	80	0	0
To three large tunnels for the principal drains across, at 200*l.* each	600	0	0
To nineteen fording places, at 10*l.* each	190	0	0
To altering bridges, and erecting a stanch for regulating the water in the mill-stream	600	0	0
To extra expenses in continuing the navigation to Stewardson mill, by erecting a lock, and making a cut from the canal to the river	500	0	0
To ditto, on account of ditto, in making a stop in the river below the going out of Stewardson's mill-stream, and in the erecting gates for the continuance of the navigation	500	0	0
	£.7720	0	0

Land to be purchased for this work, thirty-six acres.

FROM NEWMAN'S WEIR TO, AND INCLUDING, KING'S WEIR.

To digging one mile and three furlongs of canal, at 33*l.*	825	0	0
To four locks, penning twenty-one feet	2100	0	0
Carried forward	£.2925	0	0

* The sum of 1688*l.* is wrong, but it was so delivered in.

	£.	s.	d.
Brought over	2925	0	0
To three tail bridges to ditto, at 15*l.*	45	0	0
To a road bridge to Waltham Abbey	90	0	0
To one ditto, answerable to Hollifield bridge	70	0	0
To one aqueduct bridge over the Cheshunt mill-stream	200	0	0
To three large tunnels for draining, under the canal, at 150*l.*	450	0	0
To a bridge and flood-gates at the head of the cut	120	0	0
To eight fording places, at 10*l.* each	80	0	0
	£.3980	0	0

Wanted for this work, twenty-five acres of land.

FROM KING'S WEIR TO, AND INCLUDING, CARTHAGENA TURNPIKE.

To a cut, one furlong seven-tenths, past Carthagena turnpike	56	2	0
To a lock, penning three feet	300	0	0
A tail bridge	15	0	0
	£.371	2	0

Wanted to purchase one acre seven-tenths of land.

FROM CARTHAGENA TO, AND INCLUDING, NEW TURNPIKE.

To a cut by new turnpike, three furlongs in length	99	0	0
To a lock, penning five feet	500	0	0
To a road bridge, answerable to new turnpike bridge	80	0	0
To clearing a shoal between the two turnpikes	85	0	0
To a tail bridge over the lock	15	0	0
	£.779	0	0

Land to be purchased for this work, three acres.

FROM NEW TURNPIKE TO, AND INCLUDING, FIELD'S WEIR.

To a cut at Field's weir, eight-tenths of a furlong	26	8	0
To a lock, penning three feet nine inches	375	0	0
To a tail bridge to ditto	15	0	0
	£.416	8	0

Land to be purchased, eight-tenths of an acre.

FROM FIELD'S WEIR TO, AND INCLUDING, WARE WEIR.

To clearing a shoal below Standstead bridge	100	0	0
To a cut from above Stanstead bridge to Ware weir, being one mile, six furlongs, and two-tenths	468	12	0
To three locks, penning eleven feet six inches	1150	0	0
To three tail bridges	45	0	0
To four fords	40	0	0
	£.1803	12	0

To be purchased for this work, fourteen acres and two-tenths of land.

FROM WARE WEIR TO, AND INCLUDING, WARE MILL.

To a cut, three furlongs, by a new passage, into Ware mill head	99	0	0
To a lock, penning eight feet eight inches	866	13	0
To a tail bridge	15	0	0
To a ford	10	0	0
	£.990	13	0

To be purchased for this work, three acres of land.

FROM WARE MILL TO THE PRESENT DELIVERING PLACE AT HERTFORD.

	£.	s.	d.
To clearing a shoal near the balance engine	150	0	0
To a cut from the elbow above Fordham's mill into Dieker mill head, five furlongs	165	0	0
To a lock, penning seven feet six inches	750	0	0
To a tail bridge to ditto	15	0	0
To a road bridge to the mill	80	0	0
To three fords	30	0	0
To deepening Dick's mill-head, proper for navigation	99	0	0
To altering bridges and other conveniences	180	0	0
	£.1469	0	0

To this work, wanted five acres of land.

GENERAL ESTIMATE

For new making and completing the Navigation of the River Lea from Bow Bridge to the delivering Place at Hertford, by such Canals as have been approved by the Trustees on their Inspection of the same, by JOHN SMEATON, *Engineer.*

Divisions of the River.	Canal.			River.			Total length.			Locks. No.	Locks. Rise.		Expense of the works.		Acres of land.	
	m.	f.	i.	m.	f.	i.	m.	f.	i.		f.	i.	£.	s.	a.	p.
From Bow bridge to Lea bridge inclusive	2	0	0	0	5	7	2	5	7	2	8	2	1688	0	16	0
From Lea bridge to, and including, Newman's weir	5	6	0	2	2	0	8	0	0	7	33	4	7720	0	36	0
From Newman's weir to, and including, King's weir	3	1	0	1	1	0	4	2	0	4	21	0	3980	0	25	0
From King's weir to, and including, Carthagena turnpike	0	1	7	1	4	0	1	5	7	1	3	0	371	2	1	7
From Carthagena turnpike to, and including, New turnpike	0	3	0	0	3	0	0	6	0	1	5	0	779	0	3	0
From New turnpike to, and including, Field's weir	0	0	8	0	6	5	0	7	3	1	3	9	416	8	0	8
From Field's weir to, and including, Ware weir	1	6	2	2	1	2	3	7	4	3	11	6	1803	12	14	2
From Ware weir to, and including, Ware mill	0	3	0	0	4	0	0	7	0	1	8	8	990	13	3	0
From Ware mill to the delivering place at Hertford	1	0	0	1	0	0	2	0	0	1	7	6	1469	0	5	0
	14	5	7	10	3	4	25	1	1	21	101	11	19217	15	104	7
Distance from Bromley lock to Bow bridge	.....			.....			0	4	8							
							25	5	9							
To making towing-paths, bridges, gates, and stiles, at £20 per mile	.....			.....			.....			...	.....		512	0		
To repairing six weirs and turnpikes, to be kept up for the use of the navigation, at £200 each	.....			.....			.....			...	.....		1200	0		
													20929	15		
Add £10 per cent upon the works for contingent expenses, and upon the lands for temporary damages	.....			.....			.....			...	.....		2093	0	10	4
													23022	15	115	1

N.B. In this estimate there is nothing included in the above for surveyors' or clerks' salaries.

LONDON, 26th of February, 1767. J. SMEATON.

NEW RIVER WORKS.

The Report of JOHN SMEATON, *Engineer, upon the Improvements making by the New River Company, near Ware, in the County of Hertford.*

AT the desire of Mr. WALTON, on Saturday, the 21st of April, 1781, I viewed the works of the New River Company made and carrying on near Ware, and made such remarks thereon as appeared to me necessary to give an answer to the question proposed to me, viz. in what manner, and how far, the alterations and enlargements that the New River Company are now making in the New River, near Ware, have a tendency to affect the mills and navigation upon the river Lea below Ware?

To answer this question distinctly, I must in the first place observe, that subsequent to all outlets for waste water to return from the company's works and streams back again into the river Lea, there is a square open tunnel of stone, through which the water passes, and is called the gage. I had not access to take the measures with exactness, but was informed it was fourteen feet in length, six feet in width, and two feet in depth. Now, if the surface of the water below the gage were of equal height, or perfectly level with the surface of the water above the gage, the water would then remain stagnant, and none would run through the gage; but if the surface of the water above the gage be but a small, and even imperceptible difference higher than the surface of the water below the gage, this difference, forming a declivity, will cause the water to run towards the lower part, and the velocity or speed wherewith it will run, will have a certain relation to the measure of this declivity; the quantity of water, therefore, taken or passing through the gage in a given time, will be proportioned to the velocity wherewith it passes. In order, therefore, that this construction called the gage may be really and truly such, or measure of a certain given quantity of water flowing through per minute, per hour, or per day, these conditions are necessary: first, that the surface of the water should be kept at a certain constant given height before it enters the gage, and at another constant certain given height after it has passed it, so that there may be a constant and equal declivity of fall from the water's surface above the gage to the water's surface below, and thereby, also, occupying the tunnel with the same degree of fulness; for if either the surface of the water above the tunnel be raised, while the surface of the water below remains at the same height, or the surface of the water below the tunnel be lowered, that of the water above still remaining at the same height; in either case, the declivity or fall from surface to surface being greater, its velocity will increase in a certain proportion, and, consequently, the quantity of water drawn through the gage in a given time will increase in the same proportion; and the same thing will happen if the surfaces of the water above and below the gage are both raised, but that above more than that below, so as to form a greater declivity or fall; for by whatever means a greater fall is produced, a greater velocity and discharge will ensue.

Something appears to have been attempted towards a regulation of the water's surface above the gage, but nothing appeared to me to have been done with that view below the gage: however, while the capacity of the river below the gage remains the same, its capacity to convey water will remain nearly the same also, and this will in some measure prove a regulation to the height of the surface of the water below the gage; but if below the gage in several reaches, impediments, and obstructions to the motion of the current are removed, which will also be the consequence of widening or deepening, or both, so as to increase the section of the river, the natural consequence will be, that a given quantity of water will be run off as

discharged at a lower surface, and if the discharge of water at the gage were entirely limited by a sluice gate, or otherwise, to a certain given quantity, the surface of the water below the gage would by this means be actually lowered considerably; but the moment the surface of the water below the gage is in any degree lowered, the tunnel of the gage being open, a greater quantity will issue in consequence of a greater declivity or fall, which, in consequence, will in part keep up the surface below to a higher pitch than it would have been, had the quantity been actually limited; that is to say, the effects of removing obstructions are in part that of creating a greater declivity at the gage, and in part, that of conveying away a greater quantity thus drawn through the gage in consequence of that greater declivity; it therefore appears to me very evident, that however laudable it may be, and is, in the New River Company to improve the water passage, considered as an aqueduct, yet the effects of widening, deepening, cleansing, and removing obstructions to the water's passage, have a direct tendency to create a greater declivity at the gage, and thereby to draw down a greater quantity of water from the river Lea, even supposing the water's surface above the gage to be kept to a regular height, which does not appear to me to be always the case, because there do not seem to me sufficient means of doing it.

I have intimated before, that the regulation of the water's height above the gage has been attempted; but this does not appear to me done in such a way as sufficiently to answer the end. The stream of water in passing from the river Lea to the gage passes by an over fall or tumbling bay, which seems intended to let the waste water go back again into the river Lea, when the surface is above a certain height upon the gage: but this over-fall can by no means fully and accurately answer the end, as being very much too short and confined: when I was there, about one inch of water was cascading over it, so that if the crown of this tumbling bay be the proper height for the water above, or before it enters the gage, the surface was then one inch above its proper height; and what effect this may have will be seen hereafter. But this is not all, for I observed a fresh watermark $2\frac{1}{2}$ inches higher than the surface then was, at which height the water had been, in my opinion, sometime in the morning of the same day; and when the water's surface was at that mark, there would have been at or about $3\frac{1}{2}$ inches water over the tumbling bay, and consequently near upon the same quantity, that is, above three inches, too much water upon the upper side, or above the gage.

The water brought down to the works proceeds originally from the river Lea, where there is constructed a piece of machinery called the balance engine, which, if kept in complete order, accurately adjusted, and left untouched, might be a great means of keeping the water at the gage more nearly to a just height above it: but from the very great difference in the admission of the water there in the morning and noon of the same day, it must follow, either that the balance-engine is much out of order and adjustment, or that the company's servants, in whose power it is left, had drawn there an occasional quantity of water: and if the latter, of whatever use it may be to the company, it cannot be considered, while in the power of their servants, as of any use towards a regulation of the water between the proprietors of water upon the river Lea and the New River Company.

The reasoning upon the matters above stated will equally hold, whether the quantity be ten cube feet or a thousand; it therefore now comes in course to give you some idea of the quantity by which the stream of the river Lea may be lessened by the operations above mentioned to the mill-owners and navigation. To do this, however, with accuracy and precision, would require more observations and measures

than can be taken in one day; but yet, what may be deduced from what I have seen and observed, may be sufficient to enable you to judge of the ground you stand upon, and whether an examination more in the detail be necessary.

When I was there, the difference, fall, or declivity at the gage, between the surface of the water above and the surface below the gage, I judged to be about an inch, or rather better: supposing the difference to be one inch, according to my computation this difference would produce a discharge (from the measures of the gage before stated) of 1100 cube feet of water per minute, that is, above thirty tuns, and nearly equal to the water expended by one of Mr. WALTON's best mills, carrying two pair of stones, and would fill a cistern lock of a middling fall in about five minutes.

Now, if the difference were four inches, the discharge would be nearly double; and if the difference or fall were fourteen inches (which I apprehend it is very practicable to procure by a suitable alteration of the New River), the quantity discharged would then be near upon the greatest possible, through that gage, viz. 3800 cube feet per minute. I would not, however, be understood, that when the water was above three inches higher than it should have been, that there was a quantity discharged due to a fall of three inches; because, for reasons already given, an increased discharge at the gage would raise the water below, and diminish the fall, so that it is probable the true difference of fall was never more than two inches, in which case, the discharge would be above 1500 feet per minute; but which, by suitable alterations in the river below, may be carried (as already mentioned) as far as 3800 cube feet.

LONDON, 3d May, 1781. J. SMEATON.

TO THE TRUSTEES OF THE RIVER LEA.

GENTLEMEN,

WHEN I attended you at Ware, at your meeting of the 21st May, by order of Mr. WALTON, for the purpose of explaining to you such matters as might arise from a consideration of my Report made to him of the 3d May, which contained my opinion of the tendency of the improvements making by the New River Company, near Ware, a copy of which Report he had caused to be communicated to you; it was, among other things, observed by you, gentlemen, on your view, that since it appeared that the surface of the water, in passing the stone gage, was lower with respect to the roof of the tunnel of the said gage, than it was with respect to the top of the two flat stones placed as marks, and referred to in the act of parliament, that therefore the tunnel of the gage was placed too high by the difference. To this I observed, that it did appear to me as if the gage was too high for the ancient marks, but that, on account of the current state of the water, this could not be fully ascertained, unless an accurate level were taken; and this you desired me to ascertain by taking a level accordingly.

I then observed to you, on considering the situation of the two flat stones, which seemed ancient marks, that they, probably, would be found not to be upon a level, as they have been generally considered, and as they are supposed to be by the wording of the act of parliament, which refers them to the level of the same head of water flowing down the Manifold ditch, and if not those two stones or marks, (the

water being directed to be kept level therewith), the one communicating with the head of water before it has passed the gage, and the other with the tail after it has passed it, will become *bonâ fide* two separate standards, one to regulate the height of the water above the gage, and the other below it, that have been originally placed with this intent, viz. to regulate the quantity of water that will pass the gage with a given descent or declivity, as is pointed out to be necessary in my said Report of the 3d of May, and to which I beg leave to refer; which matters, with what else might occur as material to the subject, in order to ascertain a just measure of water to be taken by the company, you desired me also to examine at the same time.

Accordingly, upon the 29th of May, I took a set of levels at this place, from which it appears—

1st. That the roof of the stone tunnel composing the gage is full five-eighths of an inch higher than the top of the old part of the flat stone mark, at the Chalk Island, which marks the height of the water before it passes the gage.

2dly. That the top of the tumbling bay, across the Manifold ditch, which serves as an overfall to let the overplus water taken into the balance engine, and passing by the Manifold ditch, return into the river Lea, when it is too much in quantity to be taken in at the gage, is full half an inch higher than the top of the mark at the Chalk island.

3dly. That the ancient flat stone or standard, near Chadwell spring, which communicates with the water of the New River after it has passed the gage, is near upon three-quarters of an inch lower than the flat stone at Chalk island, that communicates with the water before it has passed the tunnel.

From the above levels it appears, that if the surface of the water be kept continually to agree with the two marks, one for the head water, the other for the tail (the difference of level being three-quarters of an inch), that a constant equable quantity of water will continually flow from the Manifold ditch through the gage into the New River, according to the apparent intent of the act of parliament, because

2dly. That if the two ancient marks had been found upon a level, and the water's surface had been kept even with those marks, the water would remain stagnant in the trough or gage, and none would have run from the Manifold ditch to the New River.

3dly. That if the water be kept even with the two marks above referred to, then the gage will not be filled so as to vend a full bore by about five-eighths of an inch in height or depth.

4thly. That if the gage be made to vend a full bore of water, then the water must be kept full five-eighths of an inch deep upon the Chalk island mark, and if the water be at the same time only even with the standard at Chadwell, there will then be a fall at the gage of $1\frac{1}{8}$ inch, which will be almost double to what it ought to be.

In expressing myself as above, I have referred my measures to the two ancient flat stones or marks; the one at Chalk island, after the water has passed the brick arch from the Manifold ditch, the other near Chadwell spring: because these, it appears to me, are the only marks remaining that have the appearance of having subsisted at the time of passing the act above mentioned; the gage itself, which at that time is recorded to be of wood, is now rebuilt with stone, and the constituent parts, viz. the tunnel, with white marble, which, in point of length, breadth, and height, agrees with the dimensions specified in the act.

The old flat stone near Chadwell spring appears to be entire; but one-half of the

old flat stone at the Chalk island seems to be gone, and to be replaced with one of a more modern date, which is at or near upon one-eighth of an inch higher than the old one.

Upon both the upper surfaces of the old flat stones there are grooves or channels, cut of about one-half an inch deep round about near the border, with openings to the outside, the intent of which, as it would seem to me, has been, that when the water comes near the level of the surface of the stones, it will, by flowing into these channels, the more readily shew when the surface of the water is in reality even with that of the stones; which is to me a convincing proof that the surfaces of these two ancient flat stones, are in reality the capped stones placed as standards, and referred to in the act. I must further remark, that the new part of the flat stone of Chalk island mark is not grooved like the old one, and that upon both this and Chadwell spring, flat stones are placed round, or octagonal stones, of about two inches in height, which form a step or rise of two inches, and the middle of the step is covered with a rounding cap or head, reaching some inches higher, both which steps and their caps, appear to be of workmanship much more modern than the flat grooved stones; but for what purpose there placed does not appear to me.

It is said above that the top of the tumbling bay, across the Manifold ditch, is full half an inch higher than the standard mark of Chalk island; that is, than the surface of the old part of the flat stone there, from which all my levels were taken, but it is to be understood that the top of the tumbling bay, as here taken, is the top of an iron bar which forms its crown, over which the water falls; but were this iron bar removed, so that the water might run over the stone upon which it lies, then the top of the tumbling bay there would not be higher, but rather lower, than the Chalk island standard mark. Whether this bar was placed upon the top of the stone-work in the original construction of this tumbling bay, or has been placed there since, or upon what occasion, does not appear to me; but it would seem that the whole of it has been done new since the date of the act, as there is a date upon it, I think, of 1746.

Upon the whole matter it appears clearly to me, that if the New River Company take such a body of water as will run through the tunnel of their gage, without raising the surface above the level of the roof thereof; that is, without any pen, and provided an equal depth of water flow over the two capped stones or standards, at the two places above mentioned, so as to produce a declivity equal to the difference of elevation of the surfaces of the two said stones, they would not take more water than they would by the act have been entitled to, if their gage had corresponded with the two said standards: but if the New River Company take no more water than will flow through their tunnel or gage, when the surface of the water is kept even with the two capped stones or standards, then the difference will be in their disfavour, as they will then take less water than they would have been entitled to by the act; but yet, though the surface of the water above the gage were kept even with the Chalk island mark or standard, if the surface of the water below the gage were kept below the Chadwell standard, the effect would be by increasing the declivity to draw more water through the gage than the due quantity: and the widening and deepening of the river below has a manifest tendency to produce this effect, as is fully stated in my said Report of the 3d of May; therefore, though it now happily appears that there are distinct marks by which the quantity may be regulated, yet, by means of the improvements made, the whole being in the power of the company's servants, they are able to take a quantity far exceeding that specified in the act.

Austhorpe, July 18, 1781. J. SMEATON.

RIVER URE WORKS.

The Report of JOHN SMEATON, *Engineer, upon a View of the Works upon the River Ure, taken the 27th April,* 1770.

AT the request of the committee of the Ure navigation, I proceeded this morning, attended by Mr. MYERS, Mr. PASHLEY, and Mr. MOON, from Bondgate green to Milby lock, and observed as follows:

1st. The basin at Bondgate green seems to be set out properly enough, if any thing too near the road. It seems best to place the warehouse at the head, or upper end thereof, and to bring in the water of the Skeld, in a subterraneous tunnel, through the little enclosure on the south side of the house, near the south end of the chain bridge, placing a draw-gate at the head to shut out the floods, and regulate the water, with a proper grate before it; the surface of the Skeld, as it may not be high enough to answer the level of the head canal, as now set out, and in part completed, may be raised by forming an artificial shoal or dam, a little below the flood-gate, with rubble, whose interstices being wrecked full of sand and gravel, may easily be made to pen the water to the height required, and be very durable. In some convenient part of the head canal, if beyond the high ground the better, it will be proper to place an over-fall, of at least twenty feet in length in the crown, and high enough to pen a mill's water, over the artificial shoal above mentioned, before it runs over the over-fall, in order that in dry seasons the water of the river may not run waste down the canal, after the works are filled to a sufficient height.

2dly. All the banks about Bondgate green to be made at least one and a half, but better if two feet, above the ordinary navigation's surface, supposed to make four feet depth of water, and to be at least nine feet broad at top; and in case this is not higher than the rise of the floods of the Skeld, to be increased in height till the floods will be prevented from making their way into the canal.

3dly. I staked out the remaining part of the canal from Bondgate green to Rhode's field lock, and set out the place for Rhode's field lock, and advise that the batter of the sides of the canal that remain to be done be made five feet back on each side for every three feet perpendicular.

4thly. The rise, according to Mr. JESSOP's levels, from the upper gate thresholds of the Oxclose lock to the surface of the water in the head level, as now set out, is twenty-five feet; but, as it was proposed to raise the water in the reach above Oxclose lock one foot extra, that is, to five feet above the upper threshold of the said lock, there will then remain twenty feet for the difference between the surface of the water in the reach over Oxclose lock, and the surface of the water in the head level, to be divided into two locks' rises; but, being informed by Messrs. MYERS, PASHLEY, and MOON, that the bottom of the cut, as it now stands finished below Bell Furrows locks, is yet two feet higher than the upper gate threshold of Oxclose, it will follow that either this cut must be deepened from Bell Furrows lock-tail, for a considerable length downwards, that is, in all the deep part of it, or the water must be raised two feet extra, that is, to six feet upon the threshold of Oxclose lock; and observing upon view, that the sides stand very steep in the deep cut, and the bottom narrow; observing, also, that Oxclose lock is built sufficiently high and strong to bear an additional extra rise of two feet, I look upon it as far more eligible to do this, than to deepen the cut. In this case, the banks of the cuts in the low grounds next Oxclose lock will require to be heightened and strengthened, and the waste holes in

the upper gates to be stopped, and in lieu thereof, to place a side wash or over-fall, near above the lock, for discharging the waste water into the river, the crown to lie about two inches above the gage height of the canal's water, that is, six feet two inches above the threshold, to be twenty feet length in the crown, but the stone setting may be contracted to ten feet at the tail: this being the case, there will remain nineteen feet difference between the upper and lower reaches of the canal, to be divided into two equal rises of nine feet and a half each; in consequence, the piquet at Bell Furrows lock, set by Mr. JESSOP, being fifteen feet nine inches above the upper gate threshold of Oxclose, it will be thirteen feet nine inches above the lower gate threshold of Bell Furrows, four feet three inches above the upper gate threshold of Bell Furrows, and the same above the lower gate threshold of Rhode's field, that is, three inches above the surface of the water in the reach between these two locks; then raising the upper gate threshold nine feet six inches above the lower at Rhode's field lock, the same as at Bell Furrows, the whole will answer to make four feet water in the respective reaches. It will be proper to have an over-fall, also, at Bell Furrows lock of twenty feet long, placed about three inches above gage height; these over-falls have been found absolutely necessary, even where the waste holes have been applied, to prevent damages by overflow of banks, when the cloughs of the locks next above are left running, either by carelessness, or with a design to do mischief, the waste holes not being sufficient to discharge the full bores of water from the cloughs.

N.B. As the bottom of the canal below Bell Furrows lock may not be quite two feet above the upper threshold of Oxclose, it will be proper to place the lower threshold of Bell Furrows lock at least as low as the bottom of the canal below it, and if any difference, to divide the two locks accordingly, which if not perfectly equal is not material.

5thly. It seems as if some dredging would be necessary below the tail of Oxclose lock; but of this I could not well judge, on account of a fresh in the river.

6thly. The dam at Westwick Wath, being undertaken to be completed by contract, it is sufficient to say, that I desired the undertaker, upon the place, as to the completing of his scheme, the cut being very deep, and the sides steep, it seems at present a good deal filled up, and I fear, being loose sandy matter, will continue to be troublesome, even after it is cleared.

7thly. The shoals lying below Westwick Wath, from the fresh in the river, had so much water upon them, it was not possible for me to judge whether the clearing of them, or building a small intermediate lock and dam, as originally proposed, will be preferable; nor can I properly judge of this matter but when the river is in its weakest state of currency, when it will be right to sound it with a boat. It is certain, that if the shoals can be effectually cleared, it will be preferable to a lock and dam, even if attended with a greater expense; but this I rather doubt, for in my original scheme, which was only for three feet certain water, I proposed four feet where the water was liable to be drawn down by the mills; and, therefore, supposing Boroughbridge dam to pen only one foot dead water over the shoals below Westwick, on raising it by a dam two feet higher, there would be three feet certain water; whereas, to deepen those shoals two feet, would in effect make but two feet water, when reduced one foot by the mills; the shoals must, therefore, be deepened three feet, to do the same thing by deepening as by raising the water two feet; and, by like reasoning, to secure four feet certain water, there ought to be five feet at a dead level within the pen of the mills; now, if this happens to be more than the general depth of the river between shoal and shoal, the whole will be to be deepened

from whence the shoals begin upwards; and if this be the case (which can only be determined with certainty by sounding at a proper season, which I never had an opportunity of doing), the expense may very far exceed that of a lock and dam.

8thly. Respecting the lock and tail cut at Milby, two things offered for consideration: first, a double rend in the wall, near the N.E. angle of the return of the tail wing, one being in the face of the wall next the lock's passage, the other in the flank or return of the wing. They both appear to be occasioned by a set in the foundation, probably owing to an over-weight, in extending the masonry of the wing beyond the ground timber; at the same time, as I understand, that the ground timber was not supported by any piles underneath, nor had any plank piling on the down-stream side to keep the matter under it, and but very inconsiderable plank piling on the up-stream side; this, considering that the natural bottom, as is said, was very weak and springy, renders it more to be wondered that no greater derangements have happened. At present it has the appearance of having done settling; and if so, the best thing that can be done, will be to double cramp the capping, and to cramp every other course downwards, and then running the joints full of fine terras mortar made liquid, doing about fifteen inches at a time, and then waiting till what preceded has set: but, in case any thing further appears, to drive down close to the face of the ground timber a sheet of rebated plank piling of four inches thick, which may be driven down to the level of the floor by a set; and, lastly, when by the action of the cloughs, the matter appears to be driven away from below the timber, to support the whole by dropping in a quantity of rubble to fill the same within six inches of the level of the floor, and to extend as far as the ground shall appear to be taken away, or five yards below the apron.

The other affair respecting this lock's tail is the shooting in of the land bank on the north side, which being a tender springy soil, especially as is said towards the bottom, has been in all probability occasioned by its being dug over steep, and too great a weight laid upon the top, by the matter which came out: there seems to me, at present, no effectual remedy for this, but to wheel the extra matter so much further back, that a slope may be formed of at least two to one from the level of the water's surface, upwards, and beginning the foot of the slope where the ground is whole; allowing also a set-off for the road, at or about the natural surface of the ground, then clearing away the piles and timber as much as possible, when the water is low, by dredging, or otherwise to deepen the channel, letting the loose matter come in, and gradually forming its own slope; and if, after this, a layer of rubble of about a foot thick be deposited upon the face of this underwater slope, beginning at the bottom, and diminishing the thickness upwards, in all probability the weight of this rubble will so consolidate the ground, as to prevent its sliding in future.

Austhorpe, 12th May, 1770. J. SMEATON.

THE REPORT

Of John Smeaton, Engineer, concerning the Repair of the Navigation Dam at Westwick Wath, upon the River Ure.

Having carefully computed the probable expense of building a new dam at Westwick Wath, including all materials; and also the probable expense of making up the breach, and repairing the dam as it now stands, in order to render the same effectual,

I find the difference will scarcely amount to 200*l.*; and as the old materials, I think, must be of that value in the new erection, it seems there will be no material difference in point of expense: however, as the making up and repair of the present dam may be the sooner executed, and, consequently, a saving of time in the opening of the navigation, and, though the present dam so repaired will not subsist upon principles so regular and uniform as the proposed new one, yet, as the new dam I have computed upon is but 160 feet between the land-walls, and the old dam, when made up and repaired, will be above 200; I am of opinion, upon the whole, that the repaired dam will be as safe as the new one; I am, therefore, inclined to advise the commissioners to the repair of the dam as it now stands.

The general method in which I propose to do it, is to let the timber frames stand as they now do, as a pen to the water, and to add a slope of stone on the down-stream side, extending twenty-four feet in base, and after that (that is, below the skirt) to lay in a body of rubble to the breadth of twenty-four feet more, by way of rough apron or security to the skirt. While this is doing, the breach is gradually to be filled with a body of rubble, and the top of it at last to be raised fifteen or eighteen inches higher than the crown of the dam; by this means, whenever more water than that thickness goes over the dam, it will begin to find a vent over the rubble dam likewise. When the rubble dam is made up, it will be made water-tight by throwing in upon the slope side up-stream several boat loads of gravel, which will shut up the interstices of the rubble, and a few boat loads of earth upon that will render it quite water-tight.

ESTIMATE

Of the Quantity and Sort of Materials to be used in making up the Dam and Breach at Westwick Wath.

	£.	s.	d.
The slope surface of the dam, being twenty-four feet broad, twenty inches in depth, and 100 feet wide, mean length will contain 4000 cube feet of scapelled stone, which, if brought from the quarries near Ripon, and put in place at seven-pence, will be	116	13	4
To rubble for filling under the setters, and covering the earth apron above the dam, 327 cube yards, which, if produced, and laid in place from the before mentioned quarries, at two shillings, will come to.....	32	14	0
To one cube yard of earth per foot running, in order to form an apron above the dam; this getting, and properly depositing, at 6*d.* for 100 feet	2	10	0
To rubble in the skirt apron, supposed at a medium, twenty-four feet broad, and three feet thick, will, in 120 feet length, contain 320 yards, which, at two shillings, will come to..	32	0	0
To 100 yards of rubble to line the shore on the north side along the apron, &c.....	10	0	0
To 120 feet running of bearing piles, stringed-piece and grooved sheeting, of three inches thick, and seven feet long, at thirteen shillings per foot running.....	78	0	0
To facing up the south side of the south wall of the cloughs, and putting it into the form as directed.....	15	0	0
	286	17	4
To contingencies on the above, at ten per cent	28	13	0
To making good the body of the present dam.....	315	10	4
To 3300 yards of rubble for making up the breach, at two shillings	330	0	0
To six boat loads of gravel and earth, at forty shillings each.....	12	0	0
Contingencies at ten per cent	34	4	0
To making up the breach.....	376	4	0
Total.....	691	14	4

It is to be observed, that though the prices are added to the above in order to fill up the blanks, yet the quantities are the only circumstances which can properly be ascertained by me, as a thorough knowledge of the prices of materials and carriage, upon which the sum total greatly depends, can only be had from an acquaintance with the country, and which, I apprehend, many of the commissioners to possess to a much greater extent than myself.

In regard to the rubble skirt or apron, it cannot be completed till after some considerable freshes have happened, that the holes made thereby may afterwards be filled up with a proper body of rubble, which will probably be required to secure it, and which ought to be got down in readiness, that after the floods have happened, it may be applied before any damage is done by the want of it.

If opportunity serves, the breach may be begun to be filled up, as soon as the materials can be got to the place, but not so high as to pen the water over the dam, keeping always the body of the rubble highest and strongest next the land, to prevent its widening.

The quantity contained in the above estimate supposes the breach such as it was when I saw it, viz. about thirty yards wide, and eight feet deep, at ordinary water; proper allowance must, therefore, be made for such alteration as has happened, or may happen, before it is put into a defensible state.

The first work for the body of the dam is to complete the piling of the skirt, and at the same time filling in the rubble for the body, over which the floods will go without damage. The skirt of the dam is supposed to be above water in a dry season; if it should not so happen, after the water has been let off as much as can be, the skirt must be raised, while the underside of the string-piece is about level with the surface of the tail-water.

Austhorpe, 19th January, 1771. J. SMEATON.

N.B. If the rubble cannot be put in place for 2*s*. 6*d*. per yard, or under, I believe it will be advisable to begin a new dam in a new place.

View of the Works of the Navigation of the River Ure, on Tuesday, May 14th, 1771, *by* JOHN SMEATON.

MILBY LOCK AND CUT.

THE tail of Milby lock, the wharfing on the south side wants lining with rubble inside the timber work.

The down-stream angle of the stone work of the lock on the south side is cracked in the same manner as the north side did the last year; when settled, it may be cramped and grouted (that is, filled with liquid mortar), as the former has been done.

The current over the top of the lock having taken out some of the earth behind, the walls near the upper gate turning posts should be filled with rubble, and lagged at the top to prevent its blowing out.

A breach in the south bank near the lock, should be made up and stout, and some low places where the water has run over should be raised.

A sand is said to be gathered in the cut above the bridge, and the head of the cut has a narrow bar of the original bank of the river, that has never been taken out,

over which, there is but three feet water at dam's height; if an opportunity offers of drawing down the river, both the above will be easily cleared by setting men into the water, but if not, the head may be cleared by a large rake, which will be useful on future occasions in clearing heads and tails of cuts; and the sand within the cut, whenever it proves obnoxious to the passage of vessels, may be taken out, by drawing a sheet of rebated piles across the cut above the same, to be well supported downstream by stays, and then drawing off the cut's water below by the lock's cloughs.

SHOALS IN THE REACH BETWEEN MILBY AND WESTWICK CUTS.

As the clearing of these shoals has been agreed for at the meeting on this day to a stipulated width and depth, they need no further remark.

WESTWICK CUT AND DAM.

The tail of the cut being sanded up, and there being a deep part of the river below, it is presumed the sand may be blown out by the action of the lock's cloughs; if not, it must be cleared with the rake. The wharfing at the lock's tail, it seems, will want supporting with rubble like Milby.

The cut above the lock has a breach into the river which will want to be carefully made up of a good height and strength, and the matter well consolidated; and some other places on the side next the river will want raising and strengthening where the water has run over.

The whole cut wants clearing, and the sides made more sloping; the bridge wants finishing.

The breach at the dam, though grown, it is said, about six yards wider than when I first viewed it, yet, by being less deep, I do not apprehend to be in a materially worse condition than before: this being contracted for upon particular plans and sections, which have been amply explained to the undertaker, needs no further mention here.

THE LONG CUT, &c.

The ford at Oxclose, not having been completed over the river, the part unmade is blown to a considerable depth, and unless repaired before any heavy freshes come on, what is done will require to be removed, and the whole begun in another place.

The banks at the tail of Oxclose cut will require to be guarded with rubble as the former.

The over-fall at the head of this lock will require to be constructed as per former Report, to convey the waste water: it may be done in a sloping form, with scapelled rubble setting; and the tail of the trench to convey off the water to be well guarded with rubble on entering the river or tail cut.

The terminations of the parapets of the bridges should have a heavy stone laid on each, otherwise the bricks cannot be properly supported, and will follow one another.

The banks for thirty feet at the tail of Bell Furrows lock, should be wharfed up with rubble walls, inclining about one foot in four; they may be built without mortar, but should be covered about one foot above the cut's water, with pretty heavy stones, a little scapelled by way of capping.

The tail of the drain that brings down the water from the over-fall should be conducted through the bank, and the bottom well set and secured at the termination by rubble.

The head cloughs of this lock want some amendment, and the shutting of the lower gates against the thresholds should be re-examined when the water is off.

Rhode's lock should be wharfed at the tail in the same manner as mentioned for Bell Furrows; and the north clough at the head wants rectifying.

The leakages that appear in various places near those locks are nothing more than what always happen in gravelly soils. The water is to be conducted in small gutters from lodging upon the surface of the lands for the present season, and before the next they will probably disappear. If, upon drawing off the water, any suspicious places appear, they will be best stopped by being puddled with corn mould earth.

The bank near the sunken tunnel on the south side wants considerably to be strengthened, and the mouth of the tunnel to be finished: it should be made wider at the entrance; and an upright bar or two be put down to prevent hay or bushes that may enter from choking it; some small part of the bank on the north side near the elbow next the turnpike road should be somewhat strengthened.

I apprehend it will be necessary in some convenient place in the upper reach of the cut to have a rough over-fall, something like that proposed at Oxclose; for, if the clough by which the water enters from the Skeld should happen in a flood or speat to be left running, the banks of the cut will infallibly overflow, and probably make a breach before it is discovered, especially if happening in the night; this over-fall may be made on the south side, near the said tunnel, and its water be conveyed away through the same.

Austhorpe, 29th May, 1771. J. SMEATON.

THE REPORT

Of John Smeaton, Engineer, upon the State of the Navigation of the River Ure from Ripon to Boroughbridge Lock.

Having carefully viewed and sounded the river and cuts the 28th September last, I find that when the cuts are cleaned, there will be four feet water from Ripon into Westwick lock.

From Westwick lock downwards, which is now the subject of the principal impediments, I find that in the state the river then was, viz. four inches water over Boroughbridge dam, there was no more than three feet nine inches and a half water over the threshold of the lower gates of Westwick lock, so that when the water is reduced to dam's height, and subsided nearly to a level, as in time of drought must always be the case, this, together with the soundings taken by Mr. Jessop last summer, convinces me, that in that state of the river, there will not be more than three feet water over that threshold. I found likewise that the places that had been dredged, had, at the time of my view, four, and four and a half feet water; but that in several places between and below the places that had been dredged, the river's bottom was no more than three feet and a half, and in one place, viz. at Rockcliff shoal (where I originally proposed building the intermediate dam) there was only three feet three inches, all below to the cut's mouth at Boroughbridge being at least five feet, and in general six feet and upwards of water: hence it appears, as also from Mr. Jessop's soundings taken at the time before mentioned, that in a dry season there will not be more than two feet six inches on Rockcliff shoal, with a full dam at Boroughbridge, while at all other places there will be about three feet.

From the cut's mouth to Milby lock there are some impediments; but as it is

always in the power of navigators to remove those, and there being four feet water over the upper thresholds at Milby, at dam's height, I consider this cut as capable of complete four feet water with a full dam.

It seems, therefore, that in case a three-feet navigation in dry seasons, three-and-a-half-feet in common ones, and four feet in open winter weather, will suffice, that this may be procured with a full dam at Boroughbridge by lowering Rockcliff shoal six, eight, or nine inches; but then, in case the miller of Boroughbridge mills should draw his water within head (as in dry times he can very easily do), the navigation, as it now stands, must, at those times, be considerably defective, and as the original expedient of building a dam at Rockcliff, or any other intermediate dam, may not be perfectly agreeable to the miller at Boroughbridge, he may possibly see it to be (as it most certainly is) for his interest to enter into a firm agreement with the navigators not to draw his water within dam, and to prevent its running over and wasting in dry seasons, to fix on a set of boards of nine or ten inches broad, which I can engage so to make, that they may be struck and removed at any time of flood; and if those are kept in repair at the joint expense of the navigation and mill, it will be a real improvement to the mill as well as benefit to the navigation, by giving them so much additional head of water when they most want it, and the mill will then have as good a latitude in drawing as it now has.

If the above cannot be acceded to, then it appears necessary either to lay a catch dam across the river just below the head of Boroughbridge cut, or to build a lock and dam at Rockcliff shoal as first intended.

The former expedient will cure the present inconveniences in the most effectual manner, because it will render the navigation entirely independent of the mills: but at the same time, I cannot take upon me to report, that in case the catch dam is raised as high as the mill dam (which, as the works are now laid, is absolutely necessary) there will not be a real injury to the mill; on the contrary, my opinion is, that there will be a real injury, which will require recompense, and if this recompense could be easily agreed upon it would be well, but otherwise, as it is of such a nature as not readily to be adjusted by a jury, it appears to me better to submit to some extra charge and inconvenience than embark in a troublesome piece of litigation.

The dam at Rockcliff shoal, as originally proposed, was intended to raise the water two feet, in order to clear all the shoals above without dredging; but, as now they are in a great degree cleared, it will be sufficient to raise the water there a single foot, and this may be done by a rubble dam; that is to say, by adding to the present, and making an artificial shoal, so as to keep up the water a foot above its present surface, that is, much about as high as the shoals intermediate, between this and Westwick, penned the water before they were cleared away. By the side of the shoal to be made at Rockcliff, there must be a lock to give passage to vessels, but as this lock need not be raised higher than till the vessels can go over the shoal itself, I apprehend the whole of this businees at Rockcliff may be done for about 1200*l.*, which may be more particularly estimated if this mode of relief be adopted.

When this is done, and the Boroughbridge cut cleared so as to be six inches below the upper threshold of Milby lock, together with the cut above also cleared, and particularly the tail cut of Oxclose lock, there will be then complete four feet water, with fill ponds in the driest seasons: and after the mill at Boroughbridge has drawn down one foot, there will still remain three feet in the Boroughbridge cut, and should the miller then attempt to draw and keep down his water below one foot within dam, as this cannot be with any other view than to distress the navigation, I

would then advise to lie in a shoal at the head of Boroughbridge cut, which will give him the command of the pond to one foot within head, but will prevent his wantonly drawing it lower.

I would advise that the navigation should be furnished with proper dredging utensils for making such clearances as can be done without taking off the water, the principal of which is a machine of known construction, used in the neighbouring river, called a hell rake: also a set of grooved piles with proper beams and braces, for readily taking off the water from any cut, so as occasionally to clear it by hand.

For want of the former, the head of Boroughbridge cut has never been sufficiently cleared; and for want of the latter, the silt that has been lodged there in time of floods is obliged to remain: but I am apprehensive, from the position of this cut's head, it will be so liable to gather silt, that it will be worth while to have a staunch fixed at the head; by shutting of which the water may be readily taken off the cut, and the soil, while light, washed out by a current of water.

Austhorpe, January 9, 1772. J. SMEATON.

P.S. In my Report of May 12th, 1770, I advised that the three overfals from the ponds of Oxclose, Bell Furrows, and Rhode's field locks, should be made twenty feet in the crown; now the two already constructed above Oxclose and Bell Furrow, are not above half that dimension; and though they may answer the purpose in ordinary, yet I shall not be surprised if, on extraordinary occasions, damages are done for want of a proper vent for the water, as well as from the pond from Rhode's field lock to Bondgate green, for want of one being constructed on this line: somewhat near the tunnel I apprehend will be the proper place.

J. S.

HEWICK BRIDGE.

To his Majesty's Justices of the Peace assembled in Quarter Sessions at Knaresborough in the West Riding of the County of York.

The Report of JOHN SMEATON *and* JOHN GOTT, *Engineers.*

See Plate 38. *Fig.* 5.

GENTLEMEN,

HAVING carefully viewed Hewick bridge, and the state of the river there, and having considered the several points referred to our opinion by your order of Skipton sessions for the West Riding of Yorkshire, of the 23d of July last, we beg leave to report upon the points referred to us, which are as follow:

1st. Whether any, and what damage has been done to a field adjoining to Hewick bridge, belonging to the Right Honourable Lord Grantley, by the current of the water?

2dly. How the same may be prevented?

3dly. From what cause the water takes its course, so as to press upon, and wash away the said field?

To the first we answer, that it appears to us that considerable damage has been done to the field next below the bridge, on the west side of the river; and that from the very loose texture of the ground of this field, being a very deep rich soil, it is likely that still greater damages will ensue, unless timely prevented by an adequate

remedy; but, in order to point out the remedy with greater propriety, it will be necessary to give our opinion previously upon the last point referred to us; viz.

3dly. From what causes the water takes its course, so as to press upon, and wash away the said field?

Nothing is more common than for rapid rivers, taking their course through grounds composed of fine deep soil, such as that under consideration, to make depredations upon them so as to change their course, of which very striking instances are to be seen in the meadows below this and Westwick Wath; and this kind of depredation often originates from slight, and even from unperceived causes; they are not always manifested to common perception, for it often happens that a change made in one part of the river, will be the cause of depredations on another, and which, when begun, have generally a tendency to grow worse, and not to cure themselves, or to stop, till some powerful remedy is applied.

The forming of the new arches at the two ends of Hewick bridge does not appear to us to have any direct tendency to produce the bad effect complained of; because the wear or wharfing annexed to the south-west land stool wall, as originally made, extending to or about sixty feet in a direct line, appears to us to stand in a proper direction to carry the stream of the river away from the part of the land in question, rather than towards it, or so as to make it bear harder upon it than before, and the arch at the opposite end is too remote to have any material effect as to this land; we find ourselves, therefore, compelled to seek for the cause of the disaster from some other source.

According to information given us, there was, formerly, a deep pool below the bridge, and at some distance a bed of gravel appeared in the low state of the river; at present, the pool is nearly filled up, and the gravel bed much increased in size and breadth; which having a natural tendency to divide the current of the river, will cause it, in consequence, to press hardest upon the lowest and weakest side, which is the very spot in question.

To this accession of gravel below the bridge we attribute the circumstance of the water taking its course so as to press harder upon, and wash away the said field, in a greater degree than formerly; but from what cause the gravel is deposited here, in a greater degree than it used to do, is a further question. It cannot be from the broken ground, because the water's current is in succession from the gravel towards the broken ground, and not from the broken ground towards the gravel bed; and the ground altered in opening the arches, at and above the bridge, is far too inconsiderable to produce the quantity; besides, the fine soil there is deep, and does not appear to produce gravel in great proportion.

We are therefore obliged to notice, that about a quarter of a mile above the bridge, a work has been made by which the whole channel and current of the river has been diverted, and now passes altogether through a new cut, which, in gravelly soil, and being worn considerably wider than it was originally made, large quantities of gravel have doubtless been gradually brought down the river therefrom, since its first opening in the year 1779, and still larger quantities appear to be travelling therefrom, capable of increasing the evil we have pointed out.

It is to be observed, that this cut being a work prior to the alteration of Hewick bridge, it would require a time for the gravel first loosened from the new bank and bottom of the cut to travel progressively on the bed of the river down to Hewick bridge, and it would be some time before the gravel brought down and lodged in the deep pool, below the bridge, would become perceivable. We find ourselves, therefore, obliged to consider the depredation of the river upon the ground in question, in a greater degree than formerly, and the alteration of Hewick bridge, as contemporary

events, and not that the latter was the cause of the former, but that the primary cause thereof was the making the new cut, and forcing the main current of the river to pass through it by a dam made for that purpose.

Lastly; we shall now consider the second point, viz. how the ill effects of the water's pressing harder upon the said field may be prevented?

Now it is to be observed, that by way of prevention, an addition has been made to the end of the weir before mentioned in the way of a jetty, intended by contraction to remove the gravel bed, and work a channel through it, and thereby to save and ease the weak side, which is the west; but by continuing it in the same line further out by 120 feet than the original weir, that direction has carried it too much towards the opposite side, so as too much to straiten the river in that place, which, in time of great freshes, gives it a tendency to spread when it quits the jetty, and finding the greatest declivity towards the broken ground, the set of a considerable part of the current is almost directly turned upon it; and as the rapidity of this part of the current has made itself a deep channel beyond the end of the jetty, this tends still to increase its action and pressure upon the said field.

Had Mr. SMEATON been called in before the jetty had been run out from the weir, he should have advised to have fortified the curve of the broken ground by lining it with a slope of rubble stones promiscuously thrown in, and not to have attempted to regain the ground by a jetty. As it is, it may be a matter of consideration depending upon the estimates herewith delivered, whether to carry forward the jetty 420 feet further in the direction shewn in the plan, (in which direction about four yards of its extreme end is already turned) or to remove the jetty, and dispose of its materials, so as to form a slope against the broken border, as far as they will go, completing the remainder with fresh materials, as either method we look upon as a likely, and the most practicable way to preserve the ground in question from further depredations.

References to the Plan, Plate 38. *Fig.* 5.

The black line marked B B B, shews the state of the ground before the bridge was widened.

A A, the jetty, 159 feet long.

The quantity of land washed away on the south-west side of the bridge, since it was enlarged, is one rood thirty-five perches; and it is probable, if something be not done to prevent it, that in time the water may take the greatest part of the field away.

ESTIMATE

For lining the broken Bank near Hewick Bridge with a Slope of rubble Stones, according to the Method suggested by Mr. SMEATON, *in which Case the Ground will not be gained.*

	£.	s.	d.
The length being at present 550 feet, to form a sufficient slope, will contain, at an average, three cube yards of rubble to a yard running; that is, it will contain 550 cube yards of stone, which, at 3*s.* per yard, will amount to	82	10	0
Allow for deposition and contingencies	7	10	0
	90	0	0
The estimate to continue the weir from A in the plan to B, being in length 420 feet, will cost	130	0	0

By this latter method there is a possibility the ground may be regained.

LEEDS, 1st October, 1782.

J. SMEATON.
JOHN GOTT.

BIRMINGHAM CANAL.

Queries by Mr. COLEMORE, with Mr. SMEATON'S Answers, concerning the Birmingham Canal.

QUERY 1st.—To see if the present leakage is not to be remedied, and that at a moderate expense?

Answer.—The present leakage is no ways alarming, and nothing more than what might be expected from the nature of the soil through which the canal passes for about three-quarters of a mile preceding the present termination, when particular care is not taken to prevent it. The soil is a red sand, tolerably firm, while it lies in its own natural bed, and underneath is a red sandy rock, close enough in the lump, but with open joints that frequently occur. This kind of soil is commonly, in some degree, leaky at first, and more or less so, and for a greater or less length of time, according as proper remedies have been at first applied, and in proportion as the water introduced into the canal has more or less of the requisite quality to keep it tight. This kind of soil, however, though leaky at first, in time grows tight of itself; insomuch, that it would require a greater degree of art to prevent its growing tight, were the percolation of the water through the pores of the sand for a length of time a requisite quality. I am of opinion, from what I have seen, that the most effectual methods have not been taken at first; and I am further of opinion, that had a proper use been made of the muddy water washed down from the marley and clayey grounds, &c. that do or might be made to fall into the canal in rainy seasons, by being carried in proper quantities through the course of the same, and discharged at or near the termination by means of a sluice, waste, overfal, or discharger, so as to keep up a constant movement at times, when water is abundant: I say, had this been done when the canal was opened, and at all convenient times since, instead of its being discharged by an overfal or waste, not far from the summit, and thereby the water towards the said termination rendered, in a great measure, stagnant, I am of opinion that the canal would have, by this time, been rendered so far tight as to have been without complaint.

Query 2d.—Whether it is, in its present state, considerable enough to endanger the navigation?

Answer.—I do not, in the present state of the leakage, think it considerable enough to endanger the navigation, or even to be a great impediment to it, as it appears to me that the leakage will be much more than balanced by the lockage water alone, which must be discharged from this lowest stretch of the canal, by a waste or discharger, if not by leakage; and if to this leakage we add the constant leakage of water through the locks, and the regulating water, which last Mr. BRINDLEY has, on another occasion, said may be ultimately equal to the lockage itself; I say, all these things considered, it does not appear in any degree probable, that the navigation would be endangered, even supposing, what I can by no means admit, that it were always to continue as it is.

Query 3d.—To examine what probability can be assigned of the same inconvenience attending the extension of the canal to New Hall Ring; and if the suspicion of such inconvenience be a fair and sufficient reason for the company to allege in bar of their being compelled to fulfil their agreement to bring the canal there?

To ascertain this, Mr. COLEMORE submits it to Mr. SMEATON to have the ground bored, as Mr. C. wishes to have his claim supported upon the clearest evidence, or

to abandon it if he may be called upon so to do, upon any principle of equity and fair dealing.

Answer.—Not only from the general appearances, but from pits which I caused to be dug in Mr. COLEMORE's ground, in or near the course of the proposed canal to New Hall Ring, in order to lay the strata open to view; it appears to me that the ground, from the present termination eastward, to New Hall Ring, is not less fit, and much of the same nature as that already passed through for about three-quarters of a mile preceding, and therefore must be subject to the like leakage, in proportion to its length (which is under one-quarter of a mile), supposing it to be executed in the same manner: but as I am very well satisfied that the extension may be made in such a manner as to be subject to much less leakage at first, and to be more speedily stopped, I cannot look upon the apprehensions of increasing the leakage, as sufficiently grounded to be a bar to the extension, especially when I consider the necessary supplies above mentioned, as a sufficient counterbalance, supposing the part to be made subject to a proportional leakage to that which is already made.

Query 4th.—To examine whether the termination of the canal, at New Hall Ring, be not equally convenient for the public with any other?

Answer.—This is not properly a question for an engineer to answer, who cannot be supposed to enter into the particular conveniencies attending the commerce of a large trading town in a few days; but from what I have observed of the situation, and have seen of the town, I see no reason it should not be as convenient as any other that has been pointed out to me: but I am of opinion that the greater the number of the owners of wharfs, the better it will be for that part of the trading public who are not immediately interested in the navigation.

Query 5th.—To estimate the expense of finishing the canal from its present termination to New Hall Ring?

Answer.—According to my estimate, the canal may be finished from its present termination to New Hall Ring, being 401 yards, according to the measure of Mr. YEOMAN, for the sum of 473*l.* 10*s.* exclusive of the value of two acres of land, which, at twenty-five yards broad, it will occupy, and exclusive of the particular charges that may attend the construction of the wharfs thereupon.

Query 6th.—To see if the shortest, the most expeditious, and the cheapest way the company can go from the present termination to their own ground, at the brick-kiln-piece, be not through Mr. COLEMORE's land, which lies on the east side of the Dudley road?

Answer.—This, I think, can hardly admit of a doubt; for, according to Mr. YEOMAN's measures and the plan conjointly, the present termination of the canal is nearer to the specific point in the brick-kiln-piece, by way of Mr. COLEMORE's land, than by the other tract marked through Mr. FARMER's land, by a difference of 292 yards, and the length of tunneling will be less than half as much. The practicability of doing it either way, I think, is not to be doubted; but which may prove easiest, length for length, I apprehend, cannot be certainly known but by executing them both: since, therefore, the chance of unforeseen difficulties is equal in the same length either way, the shortest runs the least risk of meeting them; and, upon equality of ground, the expense and time will be less in proportion to the distance. A shorter line may, indeed, be drawn from the present termination to the brick-kiln-piece, through the gardens and grounds of Mr. BASKERVILLE, without touching Mr. COLEMORE's; but, I apprehend, this will not be found eligible on account of damages; and, upon the supposition that the company are to carry the canal to New Hall Ring, then the distance through Mr. COLEMORE's land will be as near as any that can be drawn through Mr. BASKERVILLE's.

Query 7th.—Whether it is not probable the company would at present prefer this direction, if they had it not in view to prevent Mr. COLEMORE from making any advantage by wharfs and warehouses, and to engross them wholly themselves?

Answer.—What may be the reasons why the company would avoid coming into any part of Mr. COLEMORE's grounds, is not easy for me to say with certainty; but so far as I am enabled to judge of the matter, it carries that appearance, and so I must imagine, till the company are pleased to explain themselves otherways in a manner more satisfactory. It may, indeed, be alleged, that though this passage to the brick-kiln-piece is nearer, and can be done at less expense than by the other line, yet, when done, that the distance from the point of departure common to both is less by the latter than through Mr. COLEMORE's: and, according to Mr. YEOMAN's measure, the difference will be 114 yards, reckoning both ways from the said point; but then there will be double the length of tunnel, viz. about six chains through Mr. COLEMORE's, and at least twelve the other way, and I look upon a tunnel to be so great an impediment to the passage of vessels, when they are going in contrary directions, especially near wharfs, where they are often crowded, that the hinderance and loss of time will, upon an average, amount to far more by the increase of length of tunnel, than can be saved by a difference of distance of 114 yards: an under-ground tunnel is, in some places, an useful expedient, by substituting a less evil for a greater; yet it is still an evil always to be avoided, where it can.

Query 8th.—To consider if the canal be continued to New Hall Ring, whether the ground on the lower side of it would be hurt for building by the leakage?

Answer.—I am well satisfied the extension of the canal may be performed in such a manner, that there will be no leakage hurtful for building, as what may happen may easily be carried off in proper drains.

Query 9th.—To estimate the expense of making a brick side drain to carry off such leakage?

Answer.—I apprehend this is impossible to be done, because, on the supposition of leakage, it will be proper to make the drains according as the leakage happens to break out, and I do not apprehend the places can be assigned beforehand.

Query 10th.—To consider if any risk to the whole navigation can be incurred by extending the canal from its present termination to New Hall Ring; and whether any, or what security, need be given the company against such risk, if Mr. COLEMORE were to continue the canal on his own account?

Answer.—The extension appears to me to be attended with no difficulty, but what occurs in daily practice. I cannot admit of any risk to the whole navigation in the carrying the same into execution. I, therefore, do not see that any security can properly be expected. No human judgment is infallible; and should any thing of so extraordinary a nature happen, as absolutely to require it, the same justice of parliament which may oblige the company to extend the canal, will, on a similar application, enable the company to shut it up again: but if works were to have a negative upon them by the prospect of chances so remote as this, it would be impossible to do any thing in the way of artificial navigation.

TO THE COMMITTEE OF THE BIRMINGHAM CANAL.

The Report of JOHN SMEATON, *Engineer, upon the several Matters referred to his Inspection and Opinion by the said Committee, at a Meeting held at the Navigation Office, at Birmingham, the 9th and 10th of October,* 1782.

HAVING, in consequence of your directions and instructions, viewed the general scope of ground occupied not only by your present canal and navigation works, but also such further extensions, additions, and improvements, as you have had in contemplation; being on this view attended by your own engineer and surveyor, Mr. BULL and Mr. SNAPE; after full consideration, I am now in condition to answer some of the most material questions that you have done me the honour to refer to my inquiry.

In acquitting myself of this business, I find myself enabled to do it by taking the main body of your inquiries together, rather than by making answers to each separately; for by this method I shall be able to weave into one piece the whole bulk of matter that you have laid before me.

Your leading inquiries are, whether the course of the present undertaking, or the intended extension from the Wednesbury branch to the coal mines, with the several collateral branches, can be improved?

Having carefully viewed the several lines of extension pointed out to me, as well that leading from the New Hall branch, in the environ of the town toward Deretend and Bordsley, as that from the Wednesbury branch towards the collieries; I find the whole very judiciously and carefully laid out, so as to conduct the navigation in the best manner towards the several points proposed; and the means pointed out of returning the water by a tunnel from this low level, into the branch of the Wolverhampton canal, that is extended to Oker Hill by means of an engine there, will be very effectual, and attended with beneficial effects upon the whole navigation, as I shall more particularly shew hereafter.

In going over the several lines of this business, it forcibly strikes me that the principal leading hinge upon which the whole, both primarily and ultimately, must turn, is the procuring a sufficiency of water, not only for supplying the extensions you have proposed, but for upholding and subsisting the navigation as it now stands; and in respect whereof, the several claims made upon you by the millers, for restitution of the water intercepted for the supply of the canal, appears to me a very serious business; for as the value of all mills and streams of water capable of turning mills, which can be employed in the very extensive manufactures of this country, are very great in themselves, and also necessary powers for the very existence of the manufacturers; it, therefore, is not very easy to make a compensation in money that will be adequate to the thing taken away: besides, as the water taken away from the first, or any given mills upon a stream successively, turns the succeeding, the whole string of mills in succession have their respective claims upon you, so that the making the due and adequate satisfaction to them all, in their proper and proportionable degree, would be in a manner endless.

This, in a great measure, appears from the memorial of the gentlemen concerned in the mills of Aston brook, delivered to you gentlemen of the committee of the Birmingham canal, and bearing date the 28th of March, 1782, the matter of which memorial, though desired by you to be considered by me in the light of a secondary business, yet naturally leads to matter that appears to me the primary; and more especially as I understand that a similar demand has been urged by the gentlemen concerned in those mills, whose waters fall into the river Tame from the west side of

your summit; and which claims in proportion to their value, that is, distance from the seats of manufacture, are undoubtedly capable of being supported with equal justice and propriety.

It appears then to me, and is plainly so understood by the gentlemen who delivered the memorial above referred to, that you have no right to any water for navigation without recompense to the mills, but either such water as you can collect into your reservoirs in such rainy seasons, when the mill ponds are overflowing, and the mills fully supplied, or such water as is drawn out of the bowels of the earth from the mines, which had not previously made its appearance in springs upon the surface; and, upon this footing, the securing of an adequate supply of water at all seasons, becomes a matter of the first import, not only to the success of any extensions that may be thought proper, but for securing a continuance and permanency to the present lines of navigation.

I will, therefore, now endeavour to investigate and lay before you,

1st. The supplies of water that your present canal should take, according to calculation. 2dly, The quantities that were actually consumed during the dry months of the summer 1781; and from thence deduce the quantity of regulating water that was actually consumed, with other useful deductions, shewing how the necessary quantity of water, for the maintenance of the whole, is to be maintained and secured.

1st. The length of your present lines of canal, taken together, is $27\frac{1}{4}$ miles; this, at the mean breadth of thirty feet, gives a surface of 4,316,400 square feet. The soakage and evaporations in dry seasons, I have usually computed at the loss of one-fifth of an inch per day in depth, which, upon the whole surface as above, amounts to 71,940 cube feet: but as we have not so distinct an idea of high numbers as those of a smaller denomination, it may be more commodious to reduce our measures to that of the ordinary measures of the canal locks; which, according to my computation, at six feet deep, contain 3388 cube feet, which, for a round number, call 3400; then 71,940 will contain $21\frac{16}{100}$, which per week will amount to $148\frac{96}{100}$; say, for soakage and evaporation of the canal per week, 150 locksfull.

According to the account of the four summer months of the present year, viz. June, July, August, and September, there have passed the summit about 250 boats per week, loaded and empty; those would generally require two locksfull to a boat: sometimes, indeed, they would pass alternate, so that two boats would pass with a lockfull; that is, reckoned for each side the summit, the amount would be a lockfull to a boat; but as this only sometimes happens, to allow for unavoidable waste, we may fairly reckon two locksfull to a boat: the expense, therefore, of lockage through the summit, may be called 500 locksfull per week.

1st. The lockage of the Wolverhampton branch into the main trunk of the Staffordshire canal, is estimated at twelve boats per day loaded, and as many empty, that is, twenty-four locksfull; but the lowest lock at Autherly being a ten feet rise, will expend the same water as if they were all ten feet locks, and which will be equivalent to forty locksfull of six feet, such as the rest are, that is, 240 per week.

The account, therefore, with other intervening locks, will stand thus:—

	Locksfull.	
To lockage of vessels through the summit per week	500	
To ditto by the Autherly locks into the main trunk	240	
Total lockage per week		740
Carried up ..		740

	Locksfull.	
Brought over		740
The soakage and evaporation estimated at	150	
Leakage of locksfull per day, in each string, viz. one on each side the summit (one of which will supply the Wednesbury branch also), that is, eight per day	56	
Leakage of Autherly string, four ten-feet locks will be two and two-thirds more than common locksfull per day, that is, per week, eighteen and two-thirds, say	19	
Dead stock, or regulating water		226
Total supply per estimate		965

2dly. The supplies that furnished this business in the dry months of the summer, 1781, were as follow:

	Locksfull per day.		
The Company's new engine at Smethwick	565		
Ditto engine at Spon Lane	415		
			980
	Locksfull.	Butts.	
The spring near the lock office, called Hadly's spring	1	1	
The springs, called G. Smith moor springs	7	3	
The Rood End springs	46	0	
Crosswell springs that feed Hill's mill	115	6	
			170
			1150
1. Lord Dudley's old engine	127		
2. Brown and Co. Coastly moor	54		
3. Bloomfield, the patent engine	74		
4. Wilkinson's, at Bradley moor	26		
5. Capon field new engine	15		
Penn and Co's	75		
Lane's	33		
Tomkey's	53		
Catchem moor	19		
			478
			1628
But in this period, the canal had lost so much in depth, that the vessels could only go with burdens of seventeen tons, instead of twenty-four; so that, having lost full twelve inches in depth, it would be expending from itself at the rate of, per week			73
Total of the supply			1701

N.B. The Thimble mill water and springs that used to be taken in to supply the great reservoir during this time were turned down to the mills; and hence it appears, that of the above supply, amounting to 1700 locksfull per week, only 170 of it was natural water supplied by springs, which is but one-tenth part of the whole, had the others been taken in, viz.

	Locksfull per week.	
The Thimble mill springs	45	
Hanson's pool springs	23	
	68	
To which add the western springs	170	as before.
The whole of the springs	238	would make

but about one-seventh of the whole supply.

3dly. From the two preceding statements we may draw the following:

Water furnished by springs	170
Carried forward	170

	Locksfull per week.	
Brought over	170	
Water furnished by colliery engines	478	
Ditto by loss of depth upon the whole surface of the canal	73	
Total of new water supplied to the canal per week		721
From which deduct the known consumption that never returned, viz. by lockage to Autherly	240	
By lockage of the Wednesbury branch, at one boat per day each way, will be	12	
The known consumption that never returned		252
The real weekly consumption of regulating water expended in the several articles of evaporation, soakage, leakage of locks, and waste	469	
The regulating water, as by computation preceding	225	
Weekly expense of regulating water more than computation	244	

Hence it appears, 1st. That the weekly waste of dead stock, or of regulating water, is full double to the computed quantity. 2d. That the real quantity, 469, is almost equal to 500, the quantity computed for lockage of the summit. 3dly. That the quantity of spring-water actually taken in, viz. 170 locksfull, was not one quarter of 721, the quantity of new water wanted, beside the return of the Company's engine, and had the whole of the springs been taken in, it would not have amounted to one-third of the whole supply of new water.

The quantity, therefore, produced by nature appears very inadequate to the supply of this canal in dry seasons; and, therefore, it is not be wondered, that, before the Company's engines were built, the navigation was totally stopped in dry seasons for want of waters.

For, with respect to the two reservoirs, they could afford no assistance in the case, as they would be exhausted before the pinch of the season came on, as we shall see must be the case, on comparing their contents with the weekly wants above stated.

The great reservoir at Smethwick, is computed to contain 1514 locksfull when full; but, as I am informed, if full by the winter's rains, it will have lost eight feet of its top water, by the time it is wanted; but supposing it to lose only six feet, it will then contain but 621 locksfull: the rest of the reservoirs I understand hold water pretty well, and their capacities are computed as follows:

	Locksfull.
4th. Great reservoir at Smethwick, after losing six feet at top	621
Little ditto near Mr. Hansom's	100
Titford reservoir	500
Whole content of all the reservoirs	1221

Hence, if the Company's engines were laid aside, and the summit to be supplied from the reservoirs at the rate of 500 locksfull per week, the whole, with allowance for leakage, &c. arising in this part (viz. fifty-six per week, as per first statement), would be consumed in fifteen days nearly; and, with the assistance of all the springs coming in during the time in aid, the whole would be gone in three weeks, and then the canal would be left to subsist upon the springs alone in the manner before stated, and such casual showers as do not commonly happen in the four dry months of the year, to be of much service to such an extent of navigation.

From what precedes, it plainly appears how very inadequate not only all the springs, but all the reservoirs, are towards an effectual supply of the Birmingham

canal with water. As it, therefore, must in a great measure depend upon artificial means, and as there do not appear to me any, but the same artificial means of restoring the water of the springs to those mills from which it is intercepted, it seems by far the clearest way to dismiss all the waters of the springs, and suffer them again to take their natural courses; for, though some advantage might be made in using those spring-waters for lockage from the summit each way, and a method may be pointed out, whereby precisely the same quantity of water may be let out from the level canals, extending from the foot of the Smethwick locks each way for the use of the mills, that was taken in at the summit; yet, as I know no means of effecting this, but by a continual attention to the water gages that must be constructed for this purpose, so that in all the variation of the influx, that of the efflux may be regulated conformably thereto; yet, as a misapplication will always be in the power of the person attending, so as to give the mills either less or more than their due, this, of course, will often prove unsatisfactory; and as it appears that the whole of the springs are scarcely one-third of the water wanted, and not one-fourth of the water raised by the Company's engines, what supplies the two-thirds may just as well supply the other part; for when an engine or engines are once established, with proper persons to attend them at all times, as appears to me indispensably necessary, there is only the trifling difference in the quantity of coals necessary to do the whole work, or two-third parts of it.

We are now led to remark, that though engines can return the water from the lower level to the higher, so as to answer the purpose of lockage and leakage of locks; yet, since the returning engines cannot create water, what is lost by evaporation and soakage must be a sheer loss, that must be made good by the introduction of new adventitious water, to supply the place of what is gone: but towards the fund of supply the water of the springs cannot be applied, because what sinks into the earth, and mixes with the atmosphere is lost to the mills, as well as to the navigation, and if to be supplied elsewhere, or otherwise, what will supply the mills will supply the navigation.

It has been already stated, that the quantity of regulating water, or waste of the dead stock weekly amounts to 469 locksfull, which, together with what is necessary for the lockage to Autherly, and down into Wednesbury branch, viz. 252 locksfull more, make the whole amount of new water into the Wolverhampton canal, to be 721 locksfull per week.

Now, it has been remarked, that the 469 locksfull of regulating water, actually lost, being full double of what might be expected according to my ordinary computation thereof, this is a reason why the more suspicious parts of the canal should be searched in order to try to stop the leaks: yet as the quantity of soakage depends in a great measure upon the nature of the soil through which it passes, and though in making a computation for the supplies of a canal, as the loss by soakage will always be something, and in some soils may be a very great quantity, and, therefore, some kind of allowance must be made for it; yet, as it is out of all human power to foresee or say beforehand what it will be in the particular cases, in this respect when a canal is made, calculation must submit to the experience of the particular situation, and, therefore, when the fact greatly exceeds the computation, it is, as has already been said, a good reason for looking out and examining: yet, after all, any difference that we may find may be owing to the nature of the soil; and, indeed, when we consider that many parts of the Wolverhampton canal, in passing through the colliery grounds for considerable spaces together, pass over those from under which the coal has been worked, and in several places the canal actually let down, so that

the sides need raising to an additional height, on that account we are not to wonder at extraordinary leakages; nor even if it shall prove that these extraordinary leakages are incapable of remedy; so that a canal in such a situation, being subject to these derangements, I cannot hold it in a safe situation, unless it can command a considerable redundancy of water beyond all calculation.

For these reasons we cannot reckon a less quantity of new water necessary to uphold the navigation in its present state, than what we now find, viz.:

	Locksfull per week.
5th. The nine colliery engines supply, as before stated	478
And if you take the springs amounting to	238
You have nearly the quantity	716

But as there are several colliery engines that raise, and are likely to raise, considerable quantities of water that might go into the canal, that now do not, as it will be their real interest so to do, so it will be your interest and advantage to lay such reasonable inducements before the owners of those collieries, as shall make them ready to support the canal, with all the water in their power.

Account of Engines that actually raise Water that would go into the Canal, but which is turned another Way.

	Locksfull per week.
6th. Tomkey's executors (late Wilkinson's)	107
Ditto next beyond	120
Barber's upper engine	56
Water that may be had	283
To which add the nine engines that now supply the canal	478
Here then is plainly a surplusage beyond what is found to be wanted of forty locksfull	761
In further aid, to stand against such accidents as may happen amongst the engines, it seems proper that the Company should raise the water into the canal, that is now delivered by Bickley's new engine upon the surface, which, though considerably below the level of the canal, may be done by an engine of the smallest size; the water of this engine amounts to	122
Total recommended for present service	883
Total wanted for ditto	721
Overplus	162

Besides the above, the waters of the three following working engines might be lifted up into the canal, if occasion required, that now being delivered below it, take their course a different way.

	Locksfull per week.
7th. Aston and Co.	12
Dall's hole	90
Barber's low engine	14
Further supply	116

It is very natural for the mind to suggest, that though the whole number of working engines may be at present fully sufficient to keep up the dead stock of regulating water for the canal, and also the Autherly lockage, yet, as the collieries are daily in a state of change, and successively working out, it may happen in time, that being wrought out, and ceasing to draw water, the canal may fail of supply: but in answer to this it must be observed, that so long as Birmingham, Wolverhampton, &c., are wanting coals, new collieries will be opened for their supply, which

will afford new quantities of water; and for this reason, I have brought to account only those colliery engines that I found actually at work, reserving those that were building; and those that may probably work in a short time, to balance those that may not long continue at work, on account of the fields of coals being worked out, for which they were built. The following is, therefore, a list of such engines as probably will work in a short time, with the quantity of water they may be expected to afford at twelve hours work per day, viz.:

	Locksfull per week.
Hancock and Co.'s new engine	63
Lord Dudley's new engine	79
Fownes and Co. the engine stopped on account of the coal being on fire, but water putting in to extinguish it	50
Expected supplies	192

N.B. Hancock and Co.'s seems intended to deliver into the canal; the other two will deliver below it, but being at no great distance therefrom, can be lifted into it by the smallest engines.

The following contains an Account of such other Waters as have been pointed out to me as a supply, viz.:

		Locksfull per week.
9th.	Manmoor Green, a colliery formerly worked here, whose out-burst	31
	Broadwater, a colliery formerly worked, whose out-burst here	57
	Ditto Sparrow's Forge	166
	Total of Broadwater's out-bursts	223
	Total supply of collieries out-burst water	254

Now, it is to be remarked, that it is the greatest part of twenty years since the two collieries above mentioned ceased working, and that the whole of the out-burst water goes to the supply of Gasbrook mill, near Autherly, and in dry seasons is a material part of the supply of that mill. The out-burst, near Broadwater, goes to Willingsworth Hall mill, and, in dry seasons, is a considerable part of its supply; and the out-burst that goes to Sparrow's forge, near to Wednesbury (which is by far the most considerable), is the whole supply of that work.

If the water of Broadwater colliery waste were drawn by an engine to a proper depth, I doubt not but it would bring to it the greatest part, if not the whole, of the water of the out-bursts, amounting to 223 locksfull per week, and drawn at a greater depth, doubtless the feeder would be increased; but we may be sure it would not be much increased, because, from the remains of the old engine at Broadwater, its size and powers may be gathered, and from the reputed depth from whence it drew, the quantity may be nearly estimated that it could do, which only moderately exceeds the quantity now given by the out-bursts.

The Manmoor green water may also be drawn by an engine put down to a greater depth than where it issues, and its feeder might also be probably increased, in what degree is uncertain; but as the quantity now given is a mere trifle when applied to the purposes of the canal, and the engine, by the accounts of it, was a small one, no quantity of water of consideration can be expected here; and, indeed, as both the waters of Manmoor green and Broadwater have been so long occupied by mills, though it may not amount to a legal prescription against the inheritors of the freehold, yet being in possession thereof at the time of passing the Birmingham Canal Act, I must submit it to the gentlemen of the law, whether, as respecting the canal, they would not stand upon the same grounds as other mills, as to a restitution or recompense for loss of water: and in case of application to parliament for any new

powers, they would (I speak with all due submission) doubtless, on petition, prevent the water being taken without a recompense; and, therefore, would then be established upon the same grounds as other mills possessing their water by a more ancient prescription.

But, supposing the whole of the natural waters that I have viewed, exclusive of the colliery engines, were collected for service, they would stand thus:

	Locksfull per week.	
10th. The springs	238	
Manmoor Green and Broadwater out-bursts	254	
		492
The Company's reservoirs, supposing 1221 locksfull, equally expended during the four summer months, they will amount to per week	70	
And supposing the canal itself to be lowered six inches, which, I suppose, it might be without considerable prejudice, this will amount per week to	36	
		106
Total collection, exclusive of colliery engines		598
Quantity wanted		721
Deficient		123

It has been suggested, that each of those colliery wastes may be capable, exclusive of their natural feeders, as comprehending a quantity of hollow ground from whence the coal has been worked, of containing a great quantity of water as reservoirs, to be filled yearly by the winter's rains, which, being drawn out into the canal during the summer months, without defalcation from evaporation, or soakage, will afford a material supply of water to the canal, when it is most needed.

How far at this time these hollows may exist, is altogether problematical; for the coal wrought at Manmoor green, was what is in these parts called a thin seam, that is, six or seven feet thick; and though there is not much appearance of falls from the surface, yet, the under strata may be so broken and shivered, as to fill the bulk of the cavity: besides, if this coal rest upon that kind of stratum of clayey stone, which is usual for the coal to rest upon in other parts of the kingdom, and called by various names, in this length of time it is probable, in like manner as in other places, that the pillars, by sinking into the soal, sill, or thill, the roof and soal may be so nearly come together, that but little cavity remains.

At Broadwater colliery, being upon the thick seam, the surface itself appears in many places so broken, that I have no doubt, but that a great part, if not the greatest part, of the cavity is already filled up: but if it were to happen that the Birmingham canal were to be much pressed for want of water, then it might be worth while to try those expedients; and if we suppose each of those wastes of equal capacity with the whole sum of the reservoirs the Company now have, viz. to furnish seventy locksfull per week each, that is, one hundred and forty locksfull the two, then this will exceed the deficiencies last mentioned, by seventy locksfull.

11th. The whole of the supplies of new water taken together that it seems at present practicable to procure, is as follows:

	Locksfull per week.	
By springs into the summit		238
By nine colliery engines, now delivering into the canal	478	
By three ditto, that may deliver into the canal, but do not	283	
By one ditto, that cannot deliver, but recommended to be made	122	
The supply recommended		883
By three engines that cannot deliver into the canal, but might be made to do it, if occasion required	116	
Carried forward	116	1121

	Locksfull per week.	
Brought over	116	1121
By Manmoor green, and Broadwater out-bursts	254	
By the Company's reservoirs	70	
By six inches of the canal as a reservoir	36	
Visible waters that may be procured		476
By problematical waters that may possibly be procured from Manmoor Green, and Broadwater wastes		140
Total of waters that appeared to me capable of being collected		1737

Besides all which, as the springs into the summit amount only to 238, whereas the quantity wanted there (as before stated) is 556; the difference, 318 locksfull, would be required to be raised by the Company's engines, and would be near upon the work of Spoon-lane engine.

The whole of the above statements being carefully considered, it will clearly appear, that though it may be laid down as a practicable thing to supply the present demands of the canal with water, yet it cannot be done otherwise than by taking the greatest part of it from the mills that were in possession of it before the Birmingham canal was made; besides the supply of a considerable part by the Company's returning engines. Now, as there appears a sufficiency capable of answering all probable contingences, by means of the full use of the Company's engines, and a judicious application of the colliery engines' water, it cannot be doubted, but that the supply of the canal by the latter means will be the most eligible.

It may be said, indeed, suppose the owners of the collieries should refuse to deliver their water into the canal, but on such terms as might make it dearer to the Company even than paying the millers their full value? I beg leave to suggest what on other occasions I have been assured of, viz. that no man can acquire any property in water, otherwise than in regard to the use he makes of it; and, therefore, I conclude, that though the colliery owners may, at their own choice, deliver their engine water into the canal, or into a watercourse that will naturally lead it under, or away from the canal, yet that the Canal Company may, in preference of all others, take it up again, and raise it into the canal, before any third person has acquired any property therein.

RESPECTING THE PROPOSED EXTENSIONS OF THE CANAL.

1st. With respect to the extension from New Hall Ring to Deretend and Bordsley, I have already remarked, that it appears to me very judiciously laid out to conduct the navigation to the points referred to; but it will appear from the preceding statement, that it can have no water for lockage, but what is the result of a rainy season, which may probably be, *communibus annis*, about four or five months; that is, when all the mills in general have a superfluity of water, and, therefore, that a fire-engine in some proper place near New Hall Ring, with a tunnel to conduct the water thereto, will be necessary to be established along with the canal itself; for if the whole of the natural supply at the summit were to be used, it is probable it would not do more than supply the lockage of this branch, and then it will be wholly taken from the mills; for though this water were used to lock from the summit down to the present level canal to Birmingham, yet, if its equivalent be let out by gages to the mills, then this water would be wholly taken away from the lockage of this extension; but there is no doubt of its being effectually supplied, by returning the water by an engine.

2dly. With respect to the extension of the Wednesbury branch to the coal grounds lying upon a lower level towards Bliston and Darlaston, the ground also appears to me judiciously chosen to conduct the canal through this district to the points required,

and, except some deep cutting to the north-westward of Broadwater old engine, there does not appear any part of the work likely to be attended with any particular extra expense: but here again, as the lockage water from the summit is returned from the Wolverhampton canal back again to the summit, here will be no water to lock down with, into the lower level, except the surplusage of the Wolverhampton canal supply above its ordinary consumption of regulating water, that is,

	Locksfull per week.
12th. The supply being stated	883
The water wanted for other stated purposes	721
There will remain for lockage to the lower level	162

but, as this will only lock eighty-one vessels, it is plain this is not to be securely done without a returning engine, to lift the water back into the Wolverhampton level; and for this purpose nothing can be better adapted than the proposed situation at Oker hill, which will in reality be attended with several material advantages.

This proposed extension, with its branches, will measure about seven miles, which being about one quarter part of the present canal, will require for its evaporation and soakage waters about one quarter part of what the present canal requires, which being computed to be 469 locksfull per week, one-fourth of this will be 117 locksfull per week; but, the overplus being 162, it appears that there will be a supply of regulating water for the canal in this first instance, and something to spare for lockage. And when collieries are opened upon it, being intended for their immediate service, they can think it no hardship to submit to a clause, obliging them to turn all such engine water into the canal as is delivered above its level, and that the company be at full liberty to lift all such into the canal that they shall judge proper; and, in consequence, it is not to be doubted but that a quantity will be procured, not only fully adequate to the regulating water of this extension, but which, by means of the engine at Oker Hill, may be brought in aid of all such deficiencies as may happen upon the present lines by the working out of the collieries now there; and thus the whole work be permanently established.

RESPECTING THE EXPEDIENCY OF A NEW CANAL.

A new canal being said to be at this time in agitation, proposing to take up coals from the same district of country, between Wednesbury and Oker Hill, where the Wednesbury extension of the Birmingham canal is proposed to pass, and to conduct them by a different passage to the skirts of the town of Birmingham, near Deretend; and from thence away to Fazely, to join the line of the proposed canal, from the main trunk of the Staffordshire canal, at Fradley Heath, to Coventry, and so to Oxford: as a person consulted by you, it will be proper to subjoin some remarks upon the operation and expediency thereof.

And in the first place, I must observe, that what may be the necessity or expediency of conveying the Wednesbury coals to Fazely, that is, to the line of the Coventry canal, or the profits attending such conveyance, I pretend not to judge; but, whatever they might be, considered in this single point of view, they will undoubtedly turn out to be the greater, by the work itself being done upon the most direct and practicable line, and at the least expense, this being the obvious way to make a productive scheme.

What the line may be that I am told is in contemplation, I cannot completely judge of till the proposers have published their scheme; but this I observe, that the

country lying between Wednesbury and Birmingham, after quitting the valley of the river Tame, in order to get thither by way of Aston, &c. is very uneven, not naturally adapted to the course of a canal, nor yet such as that a canal can be adapted to it without incurring very large extra expenses; whereas, upon supposition that the principal object is to make a navigation from Wednesbury to Fazely, nothing can be better adapted in point of ground, through so long a course of country, than to pursue the course of the river Tame, which might be done either by conducting a canal by the course of the river's valley down to Fazely (in the whole course of which there seems nothing material to hinder) or by making the river itself navigable; or perhaps by what will be found the most eligible, practicable, and cheapest mode of all, to do it partly by one and partly by the other; that is, to make a canal where the river does not suit, and to take the river where it does. To do this by way of Salford bridge (about three miles from Birmingham) there is no natural impediment, on supposition of a competency of water.

But in lieu of a proposition so plain and evident, to take the canal out of the valley of the Tame, through every impediment, and by a much longer course, to the skirt of the town of Birmingham, and then from thence to return back into the valley of the river Tame to go down to Fazely, can certainly be intended for no other purpose than that of sharing the profits with you, that arise from the carriage of coals from the district of Wednesbury, for the supply of Birmingham, in which article I would presume that the greatest part, if not the whole of the profit of your undertaking consists.

When it is considered how many canal schemes have been abortive, how many more have fallen short of paying common interest of the vast sums of money expended upon them, in proportion to those few that have succeeded, so as to become profitable; and when it is further considered, that the few which have succeeded, have been successful in consequence of some favourable circumstances occurring, either wholly unforeseen, or not seen in the light of the capital articles of profit, which they have afterwards turned out, we must conclude, that were it not that some have proved successful, the spirit of canal making, that a few years since even raged amongst us, would be wholly extinct, and the public be deprived of the advantages further to be derived from this kind of enterprise, by which it is already found to be so largely benefited. For if in those successful cases, the proprietors are, by an act of legislature, defeated in the profit they have so dearly earned by a partition, the whole of the real motive for this kind of enterprise will be totally abolished; for, in case it were possible, in reality, to turn out a sufficient inducing profit for two, a third has an equal right to thrust in, and after that a fourth upon the same principle.

A canal has been granted running parallel to a former established navigation, but then it was where expedition and cheapness of carriage were not only offered, but insured on terms not even in any degree met by the old establishment. A canal, in a similar situation, has also been refused, though proposing greater expedition and lower terms of carriage; but the practicability of materially lowering the carriage, consistently with the necessary profit to keep the works alive, not being fully proved; and the whole proposition being met by the old proprietors on reasonable grounds, it was judged better fully to establish one, than put them both to hazard: and in both these cases, the water possessed by the former navigation was held sacred, though each of them had a large river for their supply. Much more might be said upon the above heads, and painted in stronger colours; but it comes more within my province to state the mechanical difficulties that seem to me likely to attend the establishment of a double navigation in this place.

It is principally to be remarked, what has already been clearly shewn, viz. that the Birmingham canal not only is now, but of necessity must be in future, supported by artificial means; and that this canal, independently of any one article of business done upon it, requires supporting with a dead stock of water, whose weekly consumption, or waste, amounts to no less than 469 locksfull per week; and that to do their business upon the present establishment, they necessarily require (besides the return of almost 1000 by the company's engines) 252 more, making in the whole, 721 locksfull of new water; that the whole quantity the Birmingham canal can readily command, does not exceed 883, and that is no more than necessary to have a reasonable security of having enough: yet, supposing us to calculate to a single lockfull (a task I can by no means engage to perform)

	Locksfull per week.
The exceedence here will be only	162
To which, if we add the only water that would turn off from the engines, that need not be taken up at present for the supply of the Birmingham canal, viz.	
Aston and Co., Dall's hole, and Barber's lower engine	116
The whole amount of overplus would be no more than	278

Now, if a canal of equal extent with that of Birmingham, or greater, were executed, we must expect it to require as much, or more regulating water, and lockage water, in proportion to its business. It therefore appears, that if after the Birmingham canal is barely supplied, there is not much above half as much regulating water as it must reasonably be expected to want; and if the new canal finds means to procure a part of that water which would have been drawn out of the earth, and fed the present canal, then there will be two companies depending upon the same joint stock of water, and there not being enough for both, the consequence would be, that both would greatly suffer: for if a new canal be supplied with 278 locksfull for regulating water that should have 469, there will be a deficiency of 191 locksfull; and if only half of this deficiency were deducted from the old canal, so as to create a deficiency of ninety-five locksfull per week, the very ill effect that must necessarily attend this, will appear from what was experienced in the summer of 1781; for the want only of seventy locksfull more than they were then supplied with, had reduced them a foot in depth upon the whole canal, and obliged the boats to go with such short loadings, that three boats were employed to do the business usually done by two; and had they been deficient ninety locksfull per week, the navigation must have been wholly stopped for want of depth of water in the canal, notwithstanding the power of the company's engines to return the lockage water.

It further appears, that the new canal must be in the same predicament respecting the being supported with artificial water, as the present one; for it cannot be supposed to acquire any more right over the mill waters, without restitution, than the other; and, therefore, the outburst waters of the Broadwater colliery waste cannot be applied in aid of the new canal without the same inequality and injustice as to the present one. It may be suggested, that as new collieries will be opened in consequence of a new canal, new waters will be raised by those new collieries towards its supply; but as the consumption of coals at Birmingham can only be of a limited quantity, the question will be, whether they can be more effectually carried by two canals than by one, that is, when they are both to subsist upon the same original stock of water.

A certain produce of coals, or, if I may so say, a certain number of collieries, are sufficient for the supply of Birmingham: if new collieries are opened upon the new canal, the same number less will be opened afresh, or continued upon the old; the water, therefore, drawn, that can be brought to supply the old canal, will be diminished

by the quantity brought into the new, and, since the regulating water of the two canals will be doubled, and without carrying a coal, will be nearly equal to the quantity that will effectually serve the old one in the highest state of business in short water seasons; it therefore follows, however paradoxical it may at first sight appear, that one canal may do a great quantity of business with the same water that would barely supply the waste of two.

It, perhaps, may be urged by those who would favour the new scheme, from a slight consideration of my eleventh statement, which is intended to shew, that 1737 locksfull per week is the utmost that can be obtained by an entire sweep and command of all the waters in the country which can be brought to bear, that is, without paying any regard to the rights and uses of mills now established; and therefore that this quantity divided between the two canals, that is, 868 to each, will be almost as much as I have recommended at present to be taken in, as a full supply for the now subsisting canal, viz. 883, as per sixth and eleventh statements, and more than 721, which I have ascertained to be the present necessary supply of it; yet when all the waters are deducted out of that account, that are either perfectly problematical, or already appropriated to working mills (which I apprehend to be fully as useful to the manufactures of the country as the canal itself) the overplus remaining will not exceed 278 locksfull, as before stated, even when the Birmingham canal is reduced to the bare subsistence of 721 locksfull per week.

How very hazardous it must be to the present subsisting undertaking to be circumscribed in such a narrow manner, which, going over many tracts of hollow grounds, that now contribute to make it take double the quantity of regulating water that it might be expected to do, and which will every day be increasing, must appear to every judicious person; and if it be further considered, that besides the 721 locksfull ascertained as above, and also, that there is a necessity for the company's returning engines, which raise no less than 980 locksfull, making, in the whole, 1700 locksfull per week, equal or nearly upon to the full amount of the whole country's produce, it will clearly appear, that if even this whole produce were divided between the two undertakings, that the new one would have an equal necessity to apply to returning engines, and as these would be necessary in the first instance, they would very greatly embarrass an infant project.

Having gone this length, I conclude, that it must appear to every judicious person who considers and weighs the above statements and premises, that the part of the country in question does not in reality afford the quantity of water whereon to subsist two canals, even after all artificial means are used, with the best management of the water that nature produces; and, furthermore, that which is likely to be fully sufficient for one, will be an apparent ruin to two; nay, even if the scheme were confined to the single purpose of carrying coals to Fazely, as above pointed out, which, though it would no ways interfere with the present company in point of trade, yet as the regulating water that it must subsist upon being drawn from the same sources, would evidently put the recourses of the present canal in obvious and imminent hazard. I must, therefore, conclude with suggesting, that if a canal from the Wednesbury collieries to Fazely be in reality necessary, it can be done to the best advantage by carrying forward the new proposed extension of the Wednesbury canal, by way of Walsal and Shenton to Fazely, which, being a course, as I apprehend, shorter by more than one half, the quantity of regulating water will be very greatly less, and I apprehend the additional collieries for this service would be more than adequate to the leakage; but till this course is surveyed and levelled, I forbear to speak further of it

Austhorpe, 16*th December*, 1782. J. SMEATON.

BUDE HAVEN CANAL.

The Report of JOHN SMEATON, *Engineer, upon the Practicability of a Canal proposed from Bude Haven to the River Tamar, at Calstock, in the County of Cornwall.*

HAVING viewed the country through which it has been proposed to carry this canal, and remarked the leading circumstances relative thereto, I have no doubt but that a canal is, physically speaking, practicable in the course that has been chalked out, and by means of such kind of engines and machines as have been contrived and proposed by the ingenious Mr. EDYVEAN; but how far it may be eligible and useful in point of expense to execute the whole, or any part thereof, or in any other different line or mode, which is the subject of the present question, can only be known by a careful investigation of the expense, when turned in every practical point of view.

The county of Cornwall, in general, seems but ill adapted for the making of canals across the country, being so very frequently intersected with valleys, that to preserve a level for any given considerable space between two given points, it becomes necessary to go through a vast meandering course, inasmuch that in the present case, where the distance between Bude Haven and Calstock is under thirty miles, the course chalked out for the canal, supposing it to ascend the smallest perpendicular between the two seas, at a place, on this account, called the Pack-saddle, will be above ninety miles in length.

The time allotted to look over this extensive course, with its collateral circumstances, being but seven days upon the ground, did not admit of the taking particular surveys, levels, and dimensions; and, indeed, to have done that fully and satisfactorily, would have taken as many months as I spent days upon it; but this, in fact, would have been a waste of time, because to have gone into accurate admeasurements of such schemes, that must in all probability be rejected, when at the same time the merits of the question are capable of being brought into a narrow compass, would indeed be spending time to no purpose. For this reason I have contented myself with viewing the general line and face of the country, which, assisted by the actual measures taken and observations made by Mr. EDMUND LEACH, who was desired to attend me upon this view, and who has since communicated to me, not only the measures of lengths and proposed dimensions of the canal, but many other judicious observations on these grounds, assisted by my own experience, of the probability of what is likely to happen in the execution of such a kind of work in a country so constituted, I have been able to bring together into one view comparative estimates of the different modes that appear to me the most likely to take place in the present case, from whence it may be judged by the well-wishers to, and promoters of this scheme, which is the most likely to be adapted to the capital that is practicable to raise, and which is most likely to pay interest for the capital so advanced, or—what is, as I apprehend, the same thing,—likely to be, upon the whole, the greatest advantage to the country; and if it shall appear that any of the five modes that I have particularly investigated, shall be eligible to be put in execution, then I would recommend the tract so chosen to be more particularly and carefully surveyed, levelled, and dimensions taken, from whence an estimate may be made of particulars that may be expected to come somewhat near the real expense which will be incurred, and, as I apprehend, that, in any of the ways, an amendment of the act of parliament will be required, I have, therefore, no ways confined my views to the limits thereof.

The materials that I have chiefly made use of, from the communication of Mr. LEACH, are as follow:

1st. The measures of lengths of the different districts or stages, upon the line of the canal, as he measured them, being in the whole, according to his original survey from Bude Haven to Kelly rock, upon the Tamar, in the parish of Calstock, ninety-one miles.

2d. The dimensions of the canal proposed, viz. twelve feet bottom and four feet deep, digging from three-pence to six-pence, but at an average four-pence, per cube yard.

3d. The value of the lands, which he observed to be at various prices, worth from five shillings to forty shillings annual rent; and, averaging the quantity of each sort, with the quality, he makes the value of the whole at fifteen shillings per annum; which, at thirty years' purchase, will be twenty-two pounds ten shillings per acre.

4th. The quantity of sand and lime likely to be carried annually upon the canal, wherein he observes, that the distance between Bude Haven and Kelly rock, in a right line, according to Martin's map, is twenty-eight miles, and he supposes that an equivalent surface to that of five miles on each side this direct line, that is, a surface of twenty-eight miles long, and ten milles broad, will receive benefit from this canal; in consequence, 179,200 acres of land will be concerned therein, of which he supposes one-twentieth part, that is, 8960 acres yearly, to be broken up for tillage.

He supposes further, that one half of this, viz. 4480 acres, to be manured with sand, and the other half with lime, and that the value of the carriage of each may be estimated upon what it is at Launceston, which is nearly half-way between the two extremes.

That the usual quantity of Bude or Widemouth sand, to an acre, is sixty horse seams, and weighs about eight tons, which cost in land-carriage to Launceston three pounds, but he allows ten tons to an acre and one-third, which is nearly in the same proportion.

The usual quantity of lime laid upon an acre is 100 Winchester bushels, weighing about $3\frac{1}{3}$ tons, the land-carriage of which to or near Launceston is one pound sixteen shillings; this will be ten tons to three acres.

Upon these foundations, which are sufficiently distinct, and of which every gentleman will be enabled to judge, perhaps better than myself, I have proceeded to form the comparative estimates before mentioned, according to five different propositions for executing a canal, and which are contained in five schedules, accompanying this report; and as the merit of the question is chiefly contained in what arises from these schedules, what I have further to remark will most properly come in by way of explanations, observations, and abridgements of these schedules.

Schedule 1st contains the estimates and result of the original propositions for making a canal from Bude Haven to Kelly rock, by way of the Pack-saddle, and by means of five engines, as proposed by Mr. EDYVEAN, for transferring the cargoes from the level of one canal to that of another, without the use of locks. The whole length from Bude to Tamar, at Kelly rock, being ninety-one miles, and from Bude to Launceston forty-nine miles, by the course of the canal.

The estimated capital for the execution of this work is 119,210*l.*, and the capital that is likely to be supported by the tolls upon sand and lime is 145,192*l.*, which exceeds the former by no less a sum than 25,990*l.*; and hence, upon the first face of it, it would appear to be a practicable scheme; but it must be considered and remarked, that the estimate of the expense, as it stands, is the least that, from the nature of the country, can happen; and that there is no allowance for some deep

cutting through considerable rising grounds that occur, notwithstanding so very long a course to avoid them; but exclusive of these considerations, the exceeding sum being but twenty-two per cent upon the sum estimated (at the very lowest) to be wanted; this seems inadequate to the risk of a greater cost, or less profits, or both, and also that of keeping the whole in repair; for though the articles of the carriage of coals, culm, wood, timber, iron, lime for building, corn, merchandise, &c., are not taken into the account, yet, if the profit of all these articles put together, will pay for their overseers of the repairs of the works, their clerks, toll-gatherers, &c., it will probably be as much as the tolls upon these articles will produce. As the plan thus circumstanced does not, therefore, appear to me eligible to the adventurers as it stands, we will now attend to what is stated in the next schedule.

Schedule, No. 2, contains the estimates and result of the same propositions shortened, in point of length, between Bude and Launceston, by carrying the canal over Greena moor, as pointed out by Mr. CALL; which course having viewed, I found the same practicable, and by which means a very long meandering course, up the valley of the river Altry, and several included valleys, will be avoided; and, by which means, according to Mr. LEACH, there will be cut off fifteen miles from the length.

In this tract, as Greena moor lies considerably higher than the ground at the Pack-saddle, an additional lift will be required into the canal of partition, and another engine to drop down into the former level, or works to avoid them, in all probability, of equivalent charge. I have, therefore, computed the expense on this supposition, for as the lowest land between Trenegloss and Lancast rises still much higher than Greena moor, I see no probability of a passage that way upon the same level, a circumstance recommended by Mr. CALL to be adverted to.

The total length, therefore, by Greena moor, being reduced to seventy-six miles, and the distance between Bude and Launceston to thirty-four miles.

	£.
The estimated capital is reduced to	102,087 and
The capital supposed to be supported by the tolls	146,971
The difference by which the estimated capital is exceeded by the capital supposed to to be supported	44,884

That is, forty-four per cent upon the estimated capital.

This being double per cent. upon the former, looks much more like business, but yet, in affairs of such great uncertainty, it may be advisable to look further.

Schedule, No. 3.—Suppose the northern part of the canal only to be executed, that is from Bude to Launceston, upon Mr. LEACH's original plan,

	£
The total length then being forty-nine miles, the estimated capital will be reduced to	65,228
And the capital supposed to be supported by tolls	83,440
The difference, or excess of the capital supposed to be supported above that estimated, will be	18,212

That is, twenty-eight per cent. upon the estimated capital.

Hence it appears that, compared with schedule, No. 1, the execution of the northern part of the canal, from Bude Haven to Launceston, is a safer adventure than that of the whole, and consequently a much better adventure than the execution of the southern part from Launceston to Calstock; but yet it appears that the execution of the whole upon Mr. CALL's plan, will be a better adventure, but a

much greater capital, than this; we will, therefore, next see what will come out from a partial execution of the canal upon Mr. CALL's plan.

Schedule, No. 4, contains the state of the case on supposition of executing the northern part of the canal from Bude Haven to Launceston, by way of Greena Moor according to Mr. CALL's plan.

	£
The total length thereof is thirty-four miles, and the estimated capital thereon will be reduced to	48,114
The capital supposed to be supported by tolls	84,490
The difference or excess of the capital supposed to be supported above that estimated, will be	36,376

That is, the exceedings are seventy-six per cent upon the estimated capital.

We are now arrived at not only a moderate adventure in point of capital, but a great probability of tolls answerable to the risk. Yet, as the great object appeared to be the bringing of Bude sand into the heart of the country, whether to Launceston or elsewhere; when I came into the valley of the river Tamar from the Pack-saddle, and observed how gentle its decline was, how easily practicable for a canal by locks, as far as the eye could reach, in comparison with the very long meandering course that resulted from keeping the level; I was tempted to take a further view of the valley, and found that from the point opposite the Pack-saddle, down to Greston bridge, it continues quite open, and very practicable for such a canal, and its decline is so easy, that for that length, as it appeared to me, a very moderate number of locks would make good the descent, and carry the vessels three or four miles further south than Launceston, to which place, if thought necessary, a branch canal may be carried up the valley of the Kenzie river to the bridge between Launceston and St. Stephen's. Finding this length down to Greston bridge so practicable, I was induced to examine the whole of the valley down to Calstock, to see whether there was any, and what, natural impediment to the making a navigation to the tides-way at Calstock, in case the same should hereafter be found expedient; but I found none to the making of a navigation upon the bed of the river, in the ordinary way of making rivers navigable by means of locks and dams, there being every where flat ground on one side or the other, one place only excepted, under Hingston Downs, which continues for so short a length, and the fall so easy, that a dam erected below this place would pond the water above it, so as to continue the navigation through it. Mr. CALL also pointed out the eligibility of making the gently declining valley of the Bude river navigable by locks, to the foot of the steep rising hills; now, this being done from Bude haven to the foot of Longford Hill, then ascending by engines and canals to a canal of partition at the Pack-saddle, as per No. 1, and then down to the locking canal of the Tamar valley to Greston bridge; this not only appeared the shortest way of bringing the Bude sand into the heart of the country, but seemed to be attended with far less risk and uncertainty of expense, as well as likely to be executed for the least original capital: and this has induced me to lay before the promoters of a navigable communication from Bude, a statement also of this matter, as follows:—

Schedule 5, contains the result of a scheme for executing a canal, partly by locks and partly by engines, up the valley of the Bude river, and from thence across the Pack-saddle into the valley of the river Tamar, and down that valley to Greston bridge.

	£
The estimated capital	46,108
The capital supposed to be supported by tolls	94,150
The difference by which the estimated capital is exceeded by the capital supposed to be supported	48,042

That is, exceeding by one hundred and four per cent.

Here the capital supposed to be supported, being more than double the capital estimated, affords every reasonable assurance of a successful enterprise; so that were the exceeding cost and the falling short of the tolls, to be very great, yet it is likely that on this principle there will be a sufficiency to pay the interest. Indeed, there is one article of the estimate of the expense, upon this scheme, that wants supporting by actual measures; for, with regard to the level between the point of the Tamar, opposite the Pack-saddle, and the surface of the river at Greston bridge, I can only judge of it by estimation; so that it is as possible that it may need more than ten locks, as that it may be done with less; yet, when it is considered that this canal takes in about four miles in length more of the interior of the country, to compensate for four miles next Bude Haven, whose sand will scarcely come upon the canal, except to those who lie immediately thereon: I say, this being considered, and also that by going four miles nearer the lime country, a quantity of that article will be brought to the canal by land carriage to go north, and that the expense of even three or four locks more would make no very material enlargement of the estimated capital; this appears to me to be the most secure and eligible scheme, and if so thought by the promoters of the canal, the actual taking of this level would put the affair out of doubt.

In regard to the expense of continuing the navigation by the bed of the river from Greston bridge to the tide's way at Calstock; for want of levels I can scarcely guess at it, but I am satisfied, that it may be done that way, from Greston bridge, for less money than it can be carried in any other way from Launceston to Calstock.

If this mode of execution should be adopted, I expect that on a re-survey it may appear practicable to pierce the hill at the Pack-saddle, and to go upon a level from the Tamar into the valley of the Bude, till by one single lift or engine this canal may be joined with the locking canal in the Bude valley, and thereby all transferring of the cargoes avoided, except only one; but this must depend upon a more minute inspection of particulars, the estimate now made depending upon nothing, but what I know the ground will really admit of.

It has been a question, whether machines in the manner proposed by Mr. EDYVEAN, or of any other similar construction, would do the business with sufficient dispatch; that is, whether one machine would do at each lift: but on computation from what I have already done in the way of drawing coals by water, I have no doubt but that the cargoes may be changed, without the least hurry, at the rate of one ton in four minutes; so that a cargo of twenty tons will be changed in one hour and twenty minutes; and if 1680 cargoes are carried annually in forty weeks, six days to the week, that will be seven cargoes per day, which will be changed in nine hours and twenty minutes.

I have only further to remark, that if 2*l.* 16*s.* 0½*d.* be allowed to the consumer for carrying a cargo sideways from the canal, if Bude sand is carried from Bude to Launceston, fourteen miles according to the direct line, exclusive of the crookedness and inequalities of roads, for 7*l.* 10*s.* as has been stated in the schedules; this 2*l.* 16*s.* 0½*d.* would carry it 5¼ miles in a direct line sideways, which makes good the

original supposition of taking in a space of five miles broad on each side, whereas any less allowance to the consumer would not do it.

Austhorpe, 8th Jan. 1778. J. SMEATON.

SCHEDULE, No. I.

Probable Estimate for making a Canal from Bude Haven to the river Tamar, according to the Measures designed by Mr. Edmund Leach.

The bottom Width twelve Feet, and four Feet Depth, Length ninety-one Miles.

ESTIMATE OF WORK PER MILE.

	£.	s.	d.
The bottom width being twelve feet, the slopes should be as three to five on each side; this, upon four feet depth, will contain, per mile, 14,600 cube yards, which, at four-pence per yard, will amount to	243	6	8
Allow for banking up hollow places, and extra cutting through uneven grounds, hard matter, &c. one half the above	121	13	4
The common width of ground over all, including cut and cover on both sides, for a canal of the above dimensions, will be about seventy-six feet, which will contain 921 acres per mile, which, valued at the mean price of fifteen shillings per acre annual rent, and thirty years purchase, according to Mr. Leach, will be 22*l.* 10*s.* per acre, purchase, and per mile	207	5	0
Allow half the above for extra widths in high banking and deep cutting, passing places, turning places, docks, basons, cranes, engines, temporary damages, and spoil of ground	103	12	6
To six small tunnels at 10*l.* each, and two larger ditto, at 20*l.* each, making in the whole eight subterraneous passages, per mile	100	0	0
To one road bridge per mile at 60*l.*, and two more for communication between the lands severed, at 30*l.* each, making three passages over the canal, per mile	120	0	0
To making towing-paths, back drains, fences, gates, &c. at two shillings and sixpence per yard running	220	0	0
Neat estimate per mile	1115	17	6

ESTIMATE

Of the Works of Schedule No. I., applicable to the whole length of the Canal.

To ninety-one miles of canal, at 1115*l.* 17*s.* 6*d.* per mile	101,544	12	6
To five engines for lifting and lowering the cargoes from the level of one canal to another, which, supposing the incidental expense of sinking shafts, and making tunnels, cannot be stated at less than 1000*l.* each	5,000	0	0
To building a dam, or other equivalent work, across the Bude river, for communicating the canal across the valley and river	100	0	0
To three principal aqueducts, tunnels for crossing the rivers Attry, Kenzie, and Inny, at 100*l.* each	300	0	0
To making six overfals for discharging the waste water in time of great rains, at 40*l.* each	240	0	0
To six sluices for emptying the several stretches of canal, in order to clean, &c. at 30*l.*	180	0	0
To six small shuttles and aqueducts for taking in water from the rivulets, at 10*l.* each	60	0	0
To six stop-gates for preventing the whole of the water from flowing off in the long reaches, in case of accident, or occasion for a partial cleansing and repair	120	0	0
Carried forward	107,544	12	6

	£.	s.	d.
Brought forward	107,544	12	6
To cutting an aqueduct from Shernock moor weir to the canal of partition near the Pack-saddle, being in length four miles, supposed a five-feet bottom, three feet deep, and slopes as one to one, this will contain 14⅔ cube yards per rod, say 15, which, at 1½*d.* per yard, will be 30*l.* per mile, and for four miles	120	0	0
Allow half of this for extra cutting and banking	60	0	0
The ground occupied by the aqueduct and banks will be half a chain broad, which, in four miles, will contain sixteen acres, which, if valued at the average price of 22*l.* 10*s.* will come to	360	0	0
To a new weir at Shernock moor, and stop-gates for taking water into the aqueduct..	80	0	0
In dry seasons the navigation will be likely to take all the water of the Tamar into the Shernock aqueduct, and thereby deprive the mills of Bridge rule and Langerton thereof; if we suppose the average damage done to each at 5*l.* per annum, this, at twenty years' purchase, will make a capital of	200	0	0
Neat estimate	108,364	12	6
Allow for contingencies, and unforeseen expenses upon the above, at 10*l.* per cent ..	10,836	9	3
	119,201	1	9

ESTIMATE

Of the Expense of Freight in bringing Twenty Tons of Sand from Bude Haven to Launceston by the said Canal, being in Length Forty-Nine Miles by its Course.

To filling the sand into carts or boats in the haven, and carrying it to the foot of the first engine, at 1½*d.* per ton	0	2	6
To delivering the sand into the buckets, hoisting the same, and loading and trimming the boat in the canal above, at 1½*d* per ton	0	2	6
Trackage upon the canal from the first and second engine, at 3*d.* per mile loaded going, and returning light, at 2*d.*, that is, 5*d.* per mile, upon a length of 6½ miles, by the course of the canal	0	2	8½
A trip will easily be made in this reach per day, allowing for stoppages, the boatman at 1*s.* 6*d.*, and the boat or boats to carry twenty tons, at 3*s.* together per day, 4*s.* 6*d.*	0	4	6
Expense of first reach	0	12	2½
In the second reach, changing the cargo, as in the former, at 1½*d.* per ton	0	2	6
Trackage in this reach, four miles, at 5*d.*	0	1	8
Two trips may be made in this reach per day, therefore the man and boat hire will be half-a-day, at 4*s.* 6*d.*	0	2	3
Expense of second reach	0	6	5
In the third reach, changing the cargo	0	2	6
Trackage, 38½ miles, at 5*d.*	0	16	0½
In this reach it will take three days to make a trip backwards and forwards, reckoning twelve hours to the day, at 4*s.* 6*d.*	0	13	6
Expense of third reach	1	12	0½
Ditto, of second reach	0	6	5
Ditto, of first reach	0	12	2½
Total expense of twenty tons from Bude to Launceston	2	10	8
The land-carriage from Bude to Launceston being stated by Mr. LEACH at 3*l.* per eight tons, this, for twenty tons, will cost	7	10	0
Saved upon one cargo	4	19	4
And if upon this saving we allow half to the consumer for land-carriage from the canal to his situation, and the other half to pay the interest of the capital, there will be for each purpose	2	9	8

Mr. LEACH supposes that 8960 acres of land will be manured yearly within the reach of the canal by sand and lime jointly; and supposing one half, that is, 4480 acres, be manured with sand, and the other with lime, then, as he states it, that ten tons of sand is at an average laid upon 1¼ acre, there will be wanted for 4480 acres, 33,600 tons annually, amounting to 1680 cargoes of sand annually of twenty tons each.

But 1680 cargoes, upon a profit of 2*l.* 9*s.* 8*d.* per cargo, amounts to the annual sum of 4172*l.*

Again.—It is said, that 100 bushels of lime, weight 3⅓ tons, do an acre of land at an average; therefore, 4480 acres will require 14,933 tons, equal to 746⅔, say 747 cargoes of twenty tons each, the land-carriage of which, to Launceston, is stated at 1*l.* 16*s.* per 100 bushels, that is, per cargo, 10*l.* 16*s.* Now, if the neat expense of freight is stated to Launceston at the same rate as from Bude, viz. 2*l.* 10*s.* 8*d.* which, though the distance is less, it reasonably may, on account of greater risk in carrying lime than sand, then

	£.	s.	d.
The land-carriage being	10	16	0
The water-carriage	2	10	8
There will be a saving per cargo	8	5	4
And if this be also equally divided between the consumer for land carriage, and greater waste and loss in the commodity, and the other half to the proprietors for payment of interest, there will be a profit, per cargo, of	4	2	8
And this, upon 747 cargoes, will amount to, per annum	3087	12	0
The profit upon sand, as before stated,	4172	0	0
Total	7259	12	0
Now, if 7259*l.* 12*s.* will pay the interest of a capital of	145,192	0	0
And the estimated capital be	119,201	1	9
The capital maintained will exceed the capital to be raised	25,990	18	3

that is, the estimated capital is to the exceeding, as one hundred to twenty-two, nearly.

SCHEDULE, No. 2.

State of the Case on supposition of the Execution of Mr. CALL's Proposition of carrying the Canal by Greena Moor, by which the Course of the Canal from Bude Haven to Launceston will be shortened fifteen Miles.

Saved by fifteen miles of canal, at 1115*l.* 17*s.* 6*d.* per mile	16,738	2	6
Ditto, by omission of the Shernock moor aqueduct	620	0	0
And by damages to Bridge rule and Langerton mills	200	0	0
	17,558	2	6
But, as by this scheme two more engines or lifts will be wanted, or what will amount to an equivalent expense, from this must be deducted	2000	0	0
Neat savings	15,558	2	6
Neat estimate per schedule, No. 1	108,364	12	6
Neat expense per Mr. CALL's plan	92,806	10	0
To which add ten per cent contingencies, as before	9,280	13	0
The estimated capital	102,087	3	0

ESTIMATE

Of the Expense and Freight in bringing Twenty Tons of Sand from Bude Haven to Launceston, by the Canal so shortened, being in Length Thirty-Four Miles.

	£.	s.	d.
Expense of the first reach, as before, 6½ miles	0	12	2½
Ditto, second, as before, 4	0	6	5
Ditto, third and fourth, supposed together, 8 as per last	0	12	10
In the fifth reach, changing the cargo	0	2	6
Trackage, 15½ miles, at 5*d.*	0	6	5½
A trip made in two days, man and boat, 4*s.* 6*d.*	0	9	0
Neat expense of the freight of a cargo	2	9	5
Land carriage from Bude to Launceston, as before	7	10	0
Saved upon one cargo	5	0	7
This being divided equally between the consumer and proprietors will leave to pay interest per cargo	2	10	3½
Now, 1680 cargoes of sand, at 2*l.* 10*s.* 3½*d.* amount to, per annum	4,224	10	0
And 747 cargoes of lime, as before, at 4*l.* 2*s.* 8*d.* amount to	3,087	12	0
Total per annum	7,312	2	0
But 7312*l.* 2*s.* will pay the interest of	146,971	4	0
The estimated capital	102,087	3	0
The capital maintained will exceed the capital raised	44,884	1	0

That is, the estimated capital will be to the exceeding as one hundred to forty-four.

SCHEDULE, No. III.

State of the Case upon Supposition of executing the northern Part of the Canal, that is, from Bude Haven to Launceston, upon Mr. LEACH'S Plan.

ESTIMATE OF THE EXPENSE.

To forty-nine miles of canal, at 1115*l.* 17*s.* 6*d.* per mile	54,677	17	6
To three engines for three lifts, at 1000*l.* each	3,000	0	0
To building a dam across Bude river, as before	100	0	0
To two large aqueduct tunnels for crossing the Attry and Kenzie waters, at 100*l.* each	200	0	0
To five overfals, sluices, stop-gates, and shuttles for taking in water	500	0	0
To Shernock moor aqueduct, and damage to Bridge rule and Langerton mills	820	0	0
Neat estimate	59,297	7	6
Add ten per cent. contingencies, as before	5,929	15	9
Estimated capital	65,227	13	3
Now it is supposed, that in this case, the carriage of lime will be lost, but the quantity of sand before specified in schedule, No. 1. will be carried from Bude to Launceston, viz. 1680 cargoes, leaving a profit of 2*l.* 9*s.* 8*d.* per cargo, amounting to, per annum	4,172	0	0
But 4172*l.* will pay the interest of	83,440	0	0
The estimated capital	65,227	13	3
The capital maintained will exceed the capital raised	18,212	6	9

That is, the estimated capital will be to the exceeding, as one hundred to twenty-eight.

. Consequently, the executing of the north end of the canal upon Mr. LEACH's plan from Bude to Launceston, will be a better adventure than executing the whole, and therefore much better than executing the south part from Launceston to Calstock only.

SCHEDULE, No. IV.

State of the Case on Supposition of executing the northern Part of the Canal from Bude Haven to Launceston, upon Mr. CALL's Plan.

ESTIMATE OF THE EXPENSE.

	£.	s.	d.
To thirty-four miles of canal, at 1115*l.* 17*s.* 6*d.* per mile	37,939	15	0
To five engines, at 1000*l.* each	5,000	0	0
To dams, aqueducts, overfals, and sluices, as per estimate, No. 3.	800	0	0
Neat estimate	43,739	15	0
Add ten per cent contingencies, as before	4,473	19	6
Estimated capital	48,113	14	6
Here again it must be supposed that the carriage of lime will be lost, but that the 1680 cargoes of sand will remain to be carried from Bude to Launceston, as specified in schedule, No. 1, but which leaving a profit of 2*l.* 10*s.* 3½*d.* per cargo, as per schedule, No. 2, this will yield per annum	4,224	10	0
But 4224*l.* 10*s.* will support a capital of	84,490	0	0
The estimated capital	48,113	14	6
The capital maintained will exceed the capital raised	36,376	5	6

That is, the estimated capital will be to the exceeding as one hundred to seventy-six.

Hence, it appears also, that not only the execution of the north part of the canal will be more advantageous than the whole, but that the shortening of the length will be a great advantage also.

SCHEDULE, No. V.

Scheme for executing a Canal partly by Locks, and partly by Engines, to go up the Valley of the Bude River by Locks from the Haven to the proposed Engine at Longford Hill, from thence across the Pack-saddle by Canals and Engines, as per Mr. LEACH's Plan, and then to fall down by an Engine into the Valley of the Tamar, and down that Valley by Locks and Canals to Greston Bridge.

IT is necessary to premise, that the cutting a canal in the easy declining valleys of rivers, being a matter of different consideration from that of cutting canals upon the sloping and winding sides of hills; to the latter of which the estimate for a mile of canal in Schedule, No. 1, is accommodated; a particular estimate has been made upon the same dimensions for the former; and that the advantages and disadvantages so nearly compensate one another, that as the difference turned out but a few

shillings per mile, the same price is taken in the following, as in the former estimates that uniformity may be preserved.

ESTIMATE OF THE EXPENSE.

	£.	s.	d.
To 3½ miles from Bude Haven to Longford hill, at 1115*l.* 7*s.* 6*d.*	3,905	11	3
To six locks, at 600*l.* per lock	3,600	0	0
To an engine at Longford hill, according to Mr. LEACH's plan	1,000	0	0
To four miles of canal to the next engine, at 1115*l.* 7*s.* 6*d.* per mile	4,463	10	0
To an engine for lifting the goods to the canal of partition, crossing the Pack-saddle	1,000	0	0
To two miles of canal from the second engine across the Pack-saddle beyond Thorn, where a third engine is to be placed	2,231	15	0
To the third engine to transfer the cargoes to the level of the Tamar's valley	1,000	0	0
To 15½ miles of canal from that engine to Greston bridge	17,295	1	3
To ten locks, at 600*l.* each	6,000	0	0
To two capital aqueduct bridges for crossing the Attry and Kenzie rivers, at 300*l.* each	600	0	0
To the Shernock moor aqueduct, and damage to Bridge rule and Langerton mills	820	0	0
Neat estimate	41,916	17	6
Add ten per cent contingencies, as the former	4,191	13	9
Estimated capital	46,108	11	3

ESTIMATE

Of the Expense of the Freight of twenty Tons of Sand.

Bringing the sand to the beginning of the canal, and lading the same on board the vessels, taking it as much as bringing and hoisting by the first machine, as before stated, at three-pence per ton	0	5	0
Trackage from Bude Haven to Longford hill, 3½ miles, at three-pence	0	1	5½
This distance will allow two trips per day, therefore man and boats	0	2	3
First district from Bude to Longford	0	8	8½
The second reach, as per schedule, No. 1	0	6	5
In the third reach, or canal of partition, changing the cargo into the same	0	2	6
Trackage of the canal of partition, two miles, at five-pence	0	0	10
Changing the cargo at the third machine, down to the valley of Tamar	0	2	6
In this reach three trips may be made per day, which, at four shillings and sixpence boat and man	0	1	6
Third reach, being in the canal of partition	0	7	4
In the district of canal from the third machine to Greston bridge, being about 15½ miles, at five-pence	0	6	5½
This will take two days to a trip, therefore, boat and man, at four shillings and six-pence	0	9	0
Expense of the fourth stretch, from the third machine to Greston bridge	0	15	5½
Canal of partition, or third reach	0	7	4
The second reach	0	6	5
The first stretch	0	8	8½
Total expense of freight	1	17	11
Suppose the sand at Greston bridge worth no more than at Launceston, viz. as before	7	10	0
Saved per cargo	5	12	1

	£.	s.	d.
And suppose this divided as before between the consumer and proprietors, there will be to each	2	16	0½
Suppose also the number of cargoes to Greston bridge no greater than if stopped at Launceston, that is, 1680 cargoes, at 2*l.* 16*s.* 0½*d.*	4,707	10	0
But, 4707*l.* 10*s.* will support a capital of	94,150	0	0
The estimated capital	46,108	11	3
The capital maintained will exceed the capital raised	48,041	8	9

That is, the estimated capital will be to the exceeding as one hundred to one hundred and four.

This way, therefore, appears to be the safest adventure of all.

Austhorpe, 8th January, 1778. J. SMEATON.

END OF THE FIRST VOLUME.

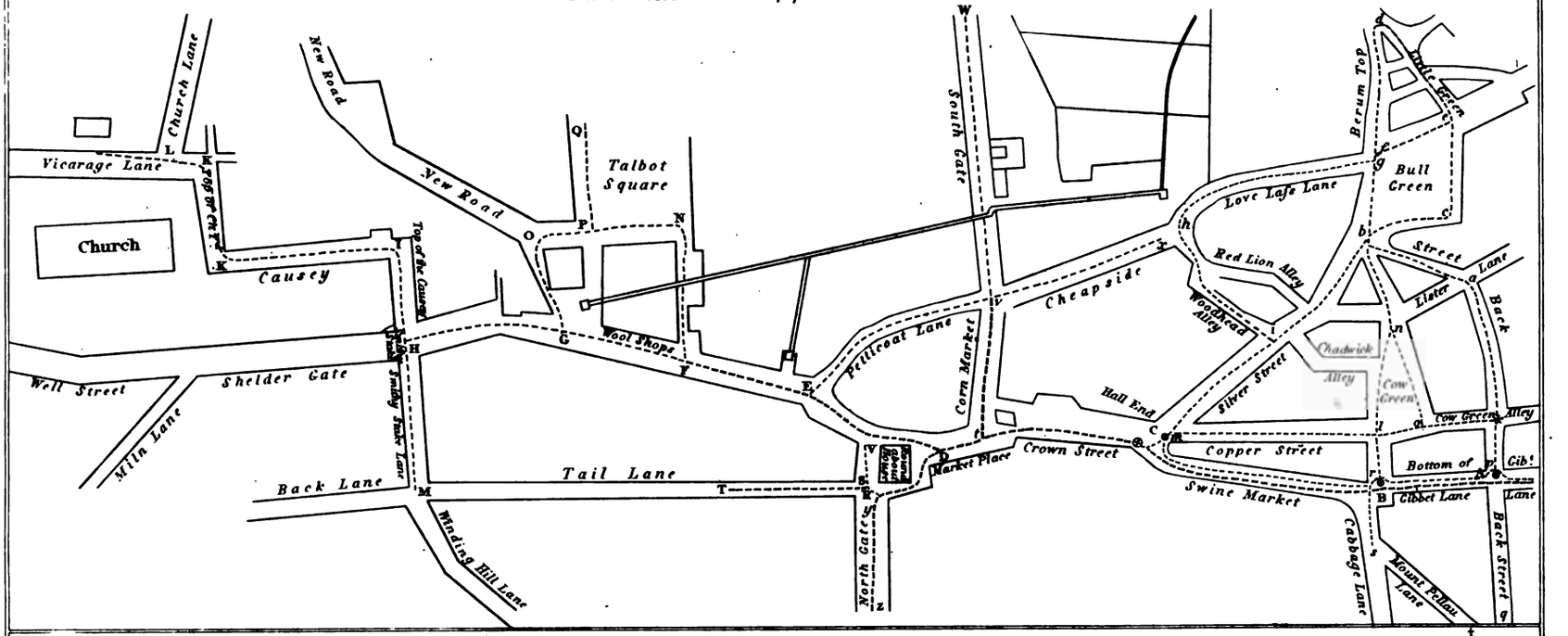
LONDON:
PRINTED BY J. MOYES, CASTLE STREET, LEICESTER SQUARE.

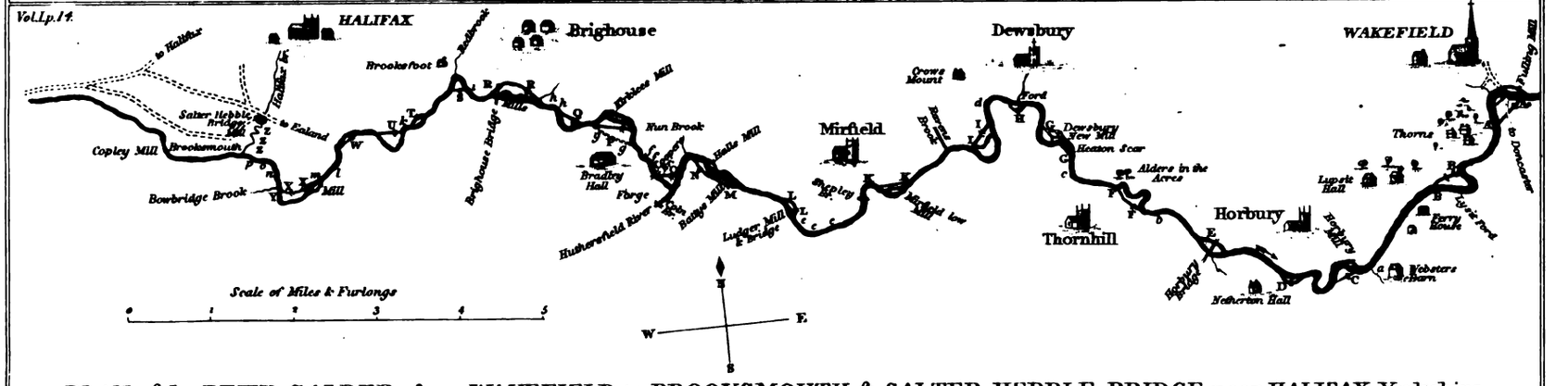
Vol I p. 5

Pl. 1.

PLAN of the TOWN of HALIFAX, shewing the PIPES for supplying it with WATER.

The lines.... denote the pipes.





PLAN of the RIVER CALDER, from WAKEFIELD to BROOKSMOUTH & SALTER HEBBLE BRIDGE, near HALIFAX, Yorkshire, with a projection for rendering the same Navigable by J. Smeaton, 1757.

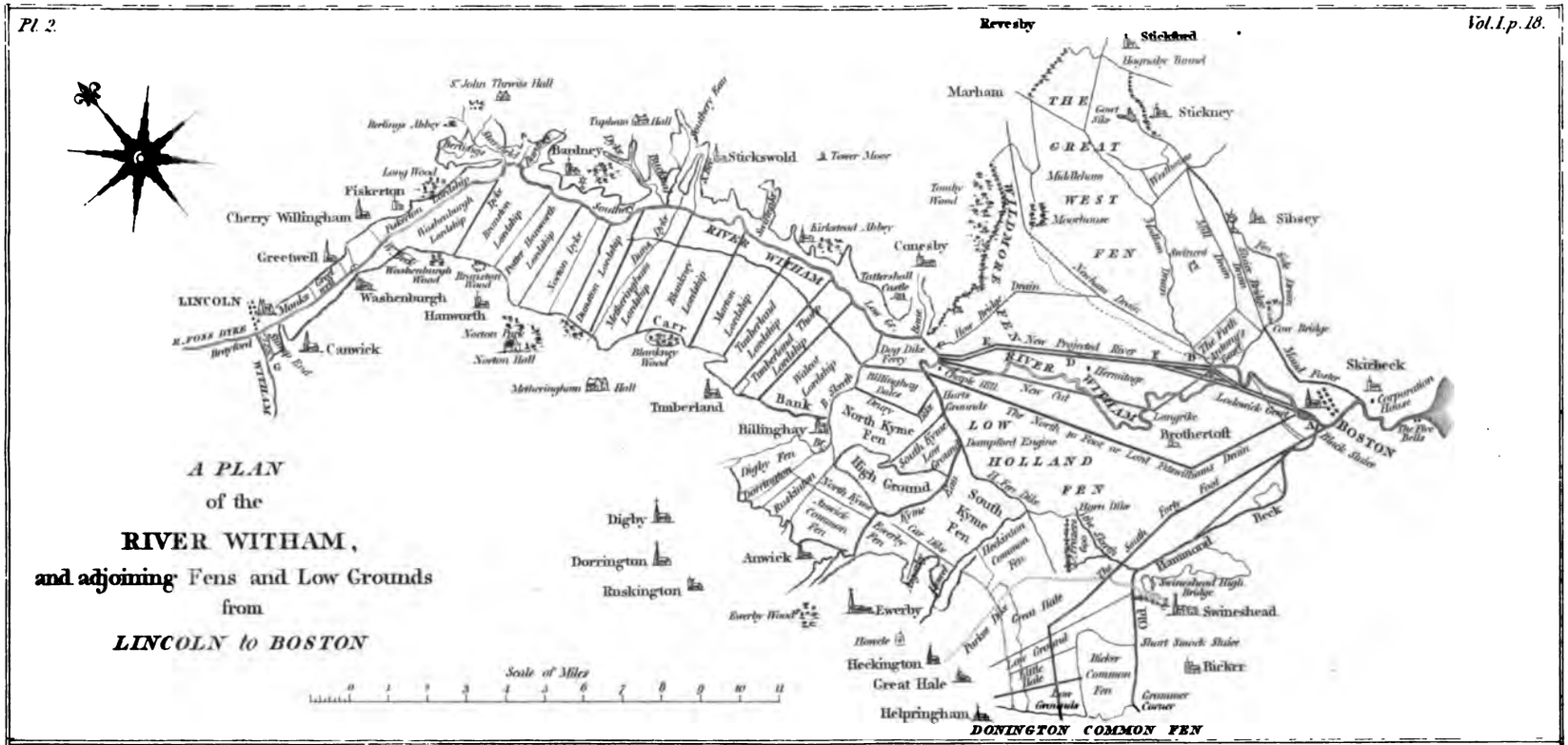
J. Farey del.

W. Lowry sculp.

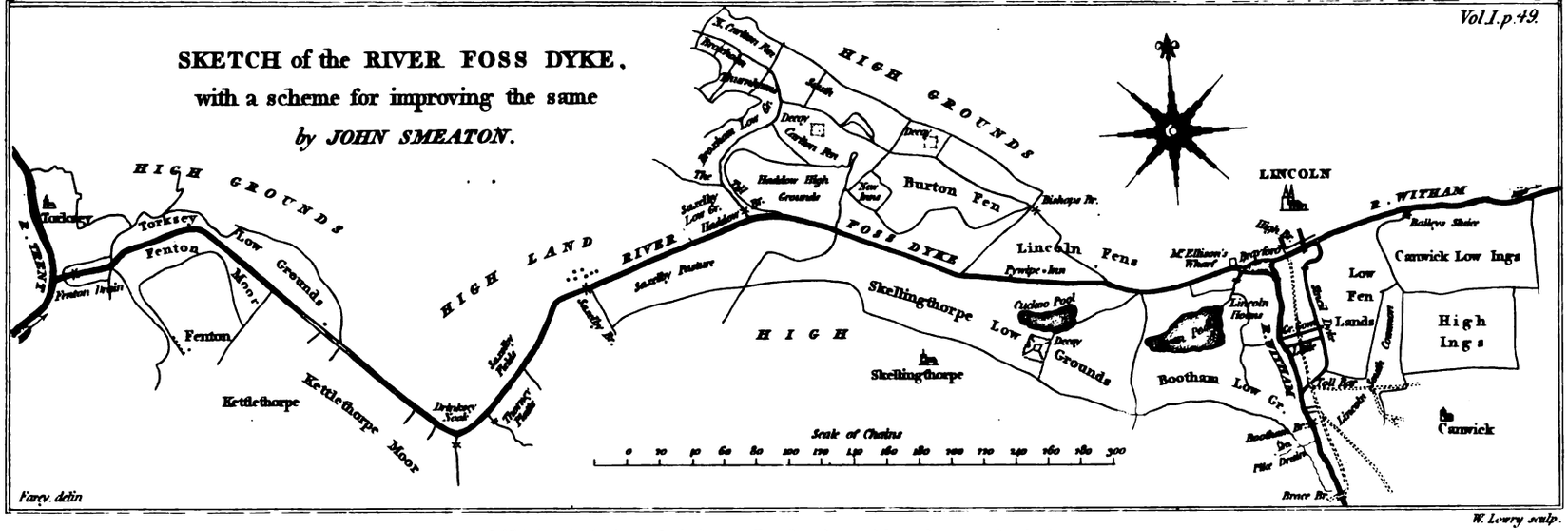
Published as the Act directs, 1st by Longman, Hurst, Rees, Orme and Brown Paternoster Row London.

Pl. 2.

Vol.I.p.18.



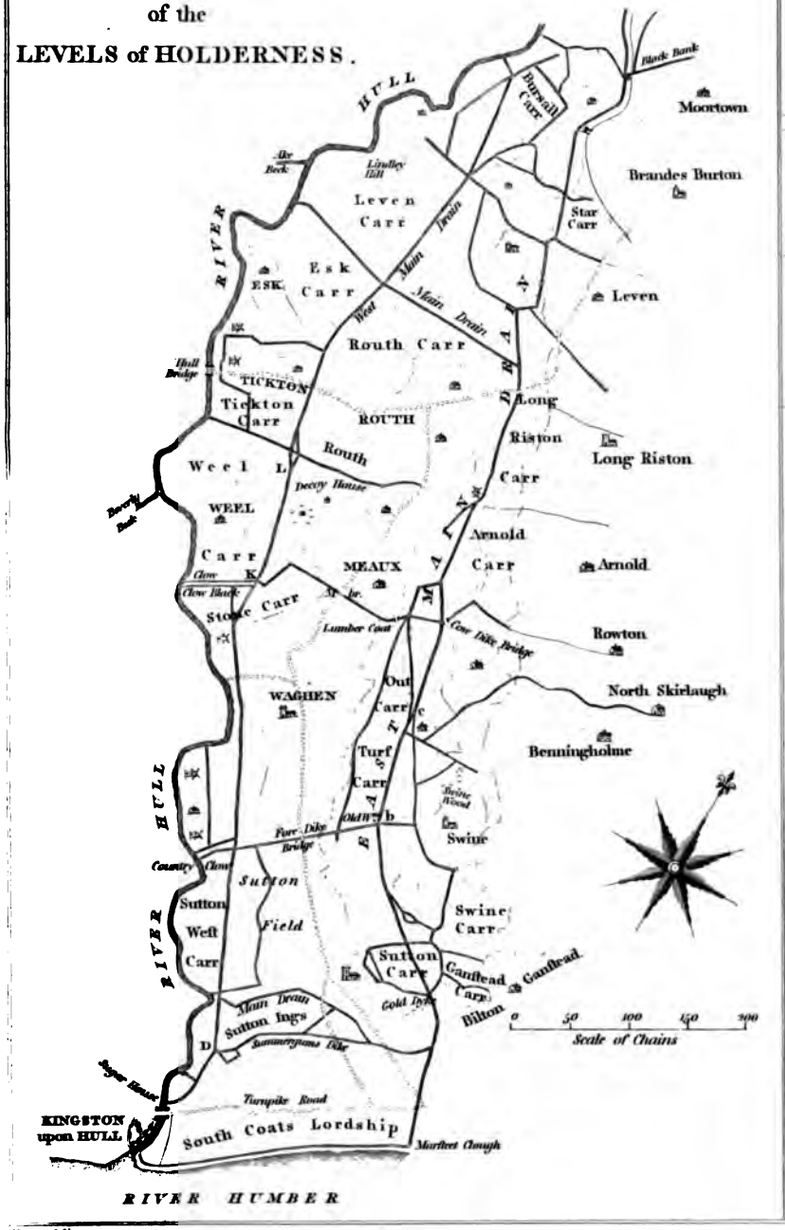
Vol.I.p.49.



Published as the Act directs 18th. by Longmen, Hurst, Rees, Orme and Brown, Paternoster Row, London.

Pl. 3. Vol. I. p. 60.

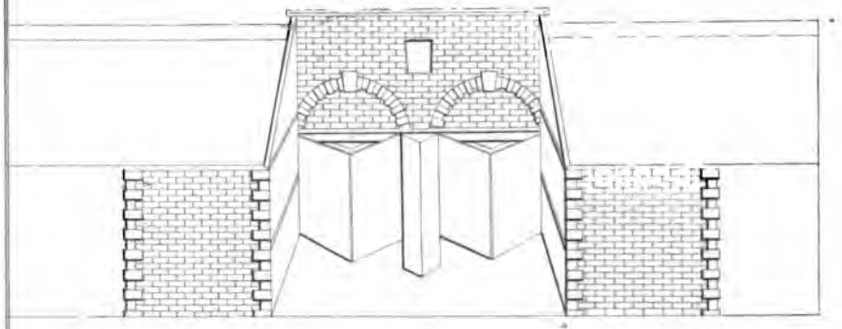
A PLAN of the LEVELS of HOLDERNESS.



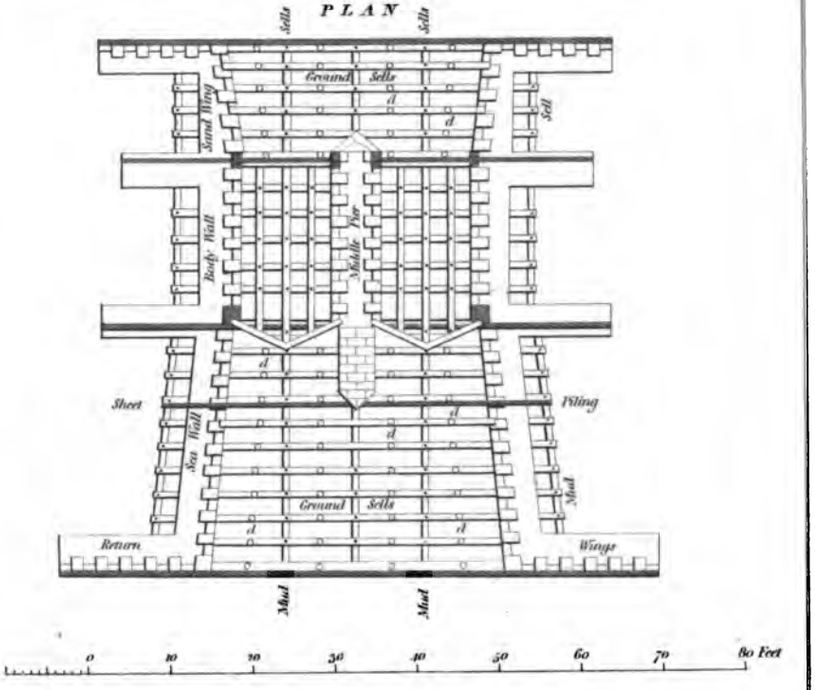
Vol. I. p. 64.

HOLDERNESS SEA SLUICE

ELEVATION SEAWARD



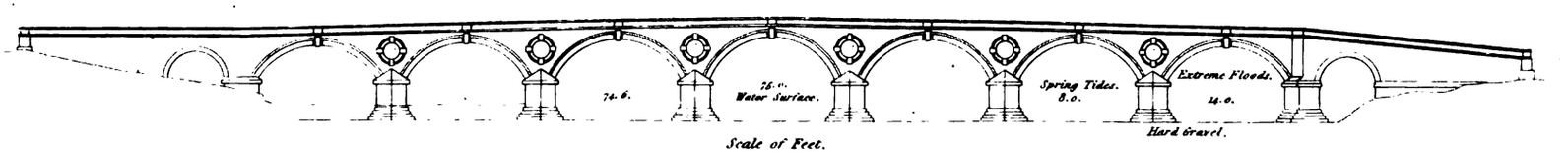
PLAN



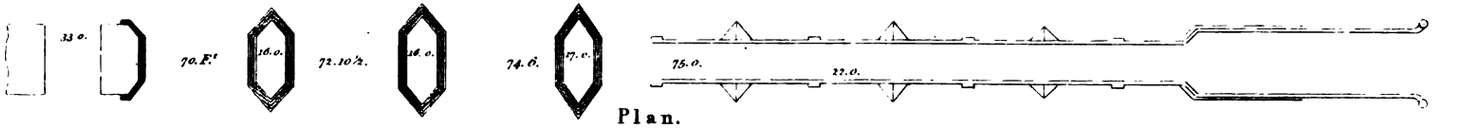
Furcy delin. W. Lowry sculp.

Published as the Act directs, 1812, by Longman, Hurst, Rees, Orme and Brown, Paternoster Row, London.

ELEVATION of the SOUTH FRONT for a STONE BRIDGE over the RIVER TAY at PERTH.

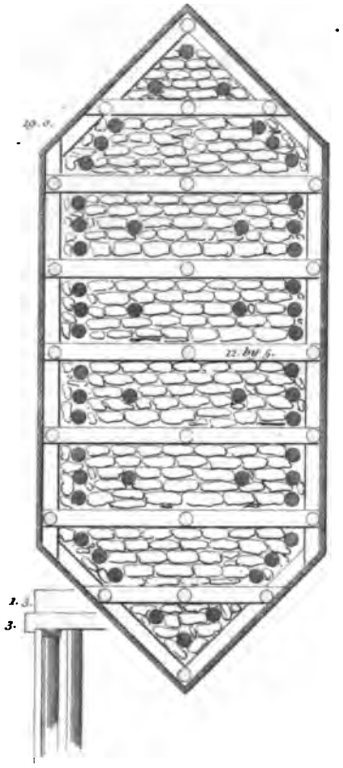


Scale of Feet.



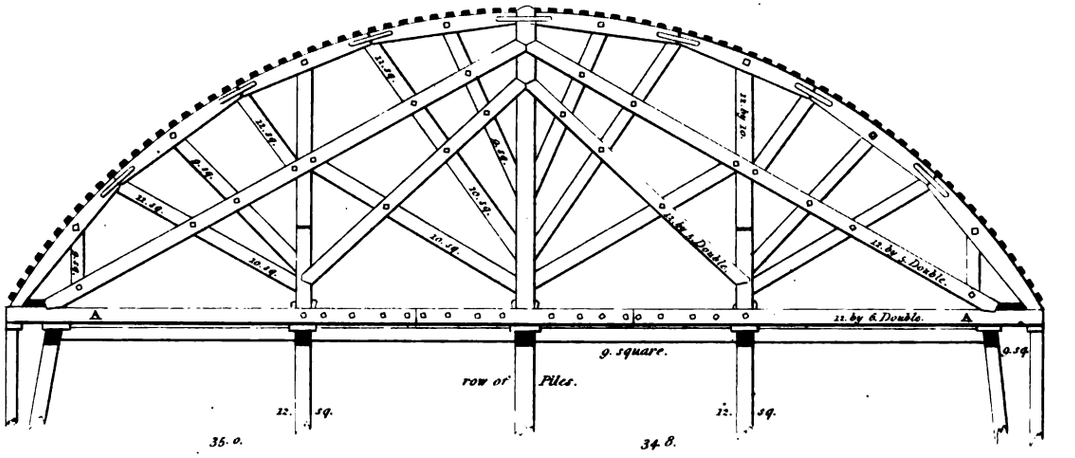
Plan.

Foundation for the Second Pier p. 128.



Scale of Feet.

Design for one of the 6 Ribs of the center for each arch p. 121.



Plan of the Tye Beams AA shewing the joinings.

Engraved by Wilson Lowry.

Published August 11, 1810, by Longman, Hurst, Rees, & Orme, Paternoster Row, London.

Vol. I p 130

Pl. 5.

A SKETCH of CHRISTCHURCH HAVEN, HAMPSHIRE.

N. *The dotted curve...round the Harbour's mouth denotes the position of a Dam for turning the water through the new proposed mouth.*

N.B. *The Proposed works which were in the Original drawn in red, are here distinguished by*

Marshes

High Land

Christ Church Heads

Iron Stones

Mud dry at Low Water

Mud dry at Low Water

Haven House Pt Low Land

Gravel Shoal

When the Soundings were taken there was 5¼ feet of Water upon the Barr.

Bearing of the Needles

THE ENGLISH CHANNEL

Vol. I p 96

PLAN for rendering the RIVER DEVON Navigable from MELLOCK FOOT to the RIVER FORTH.

English Miles

Alloa

River

Tillibodie House

Cambus Mills

Cambus Quay

Tillibodie New Mill

Tillibodie Dam

Tillibodie Bridge

Mellock Foot

Bargone

Back Mill

Mellock Glen

Tillicoultry Bridge

Dam

Tillicoultry

New Dam

Old Engine

Colgland Engine

New Dam

Gibble Brook

Vent Mill

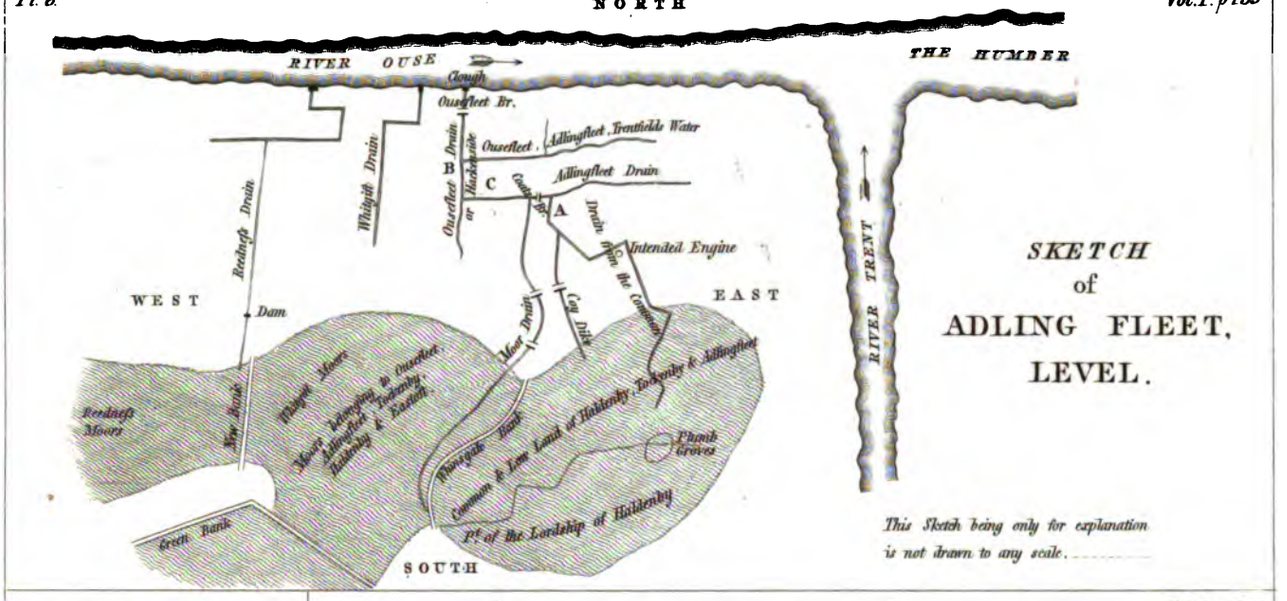
Vicars Bridge

J. Farey del.

W. Lowry sculp.

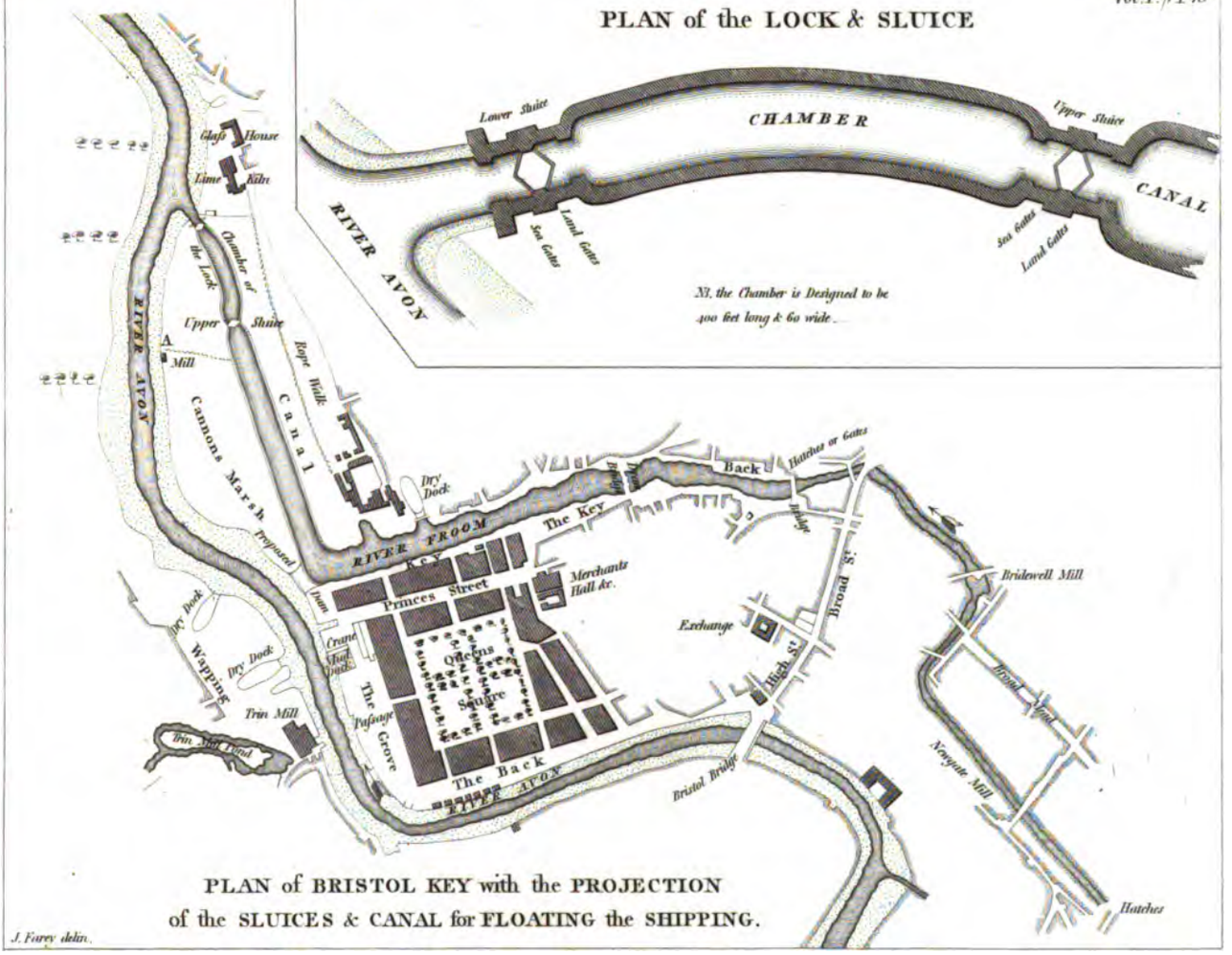
Published as the Act directs 1811 by Longman Hurst, Rees, Orme and Brown Paternoster Row, London.

Pl. 6. NORTH Vol. I. p 135



Vol. I. p 149

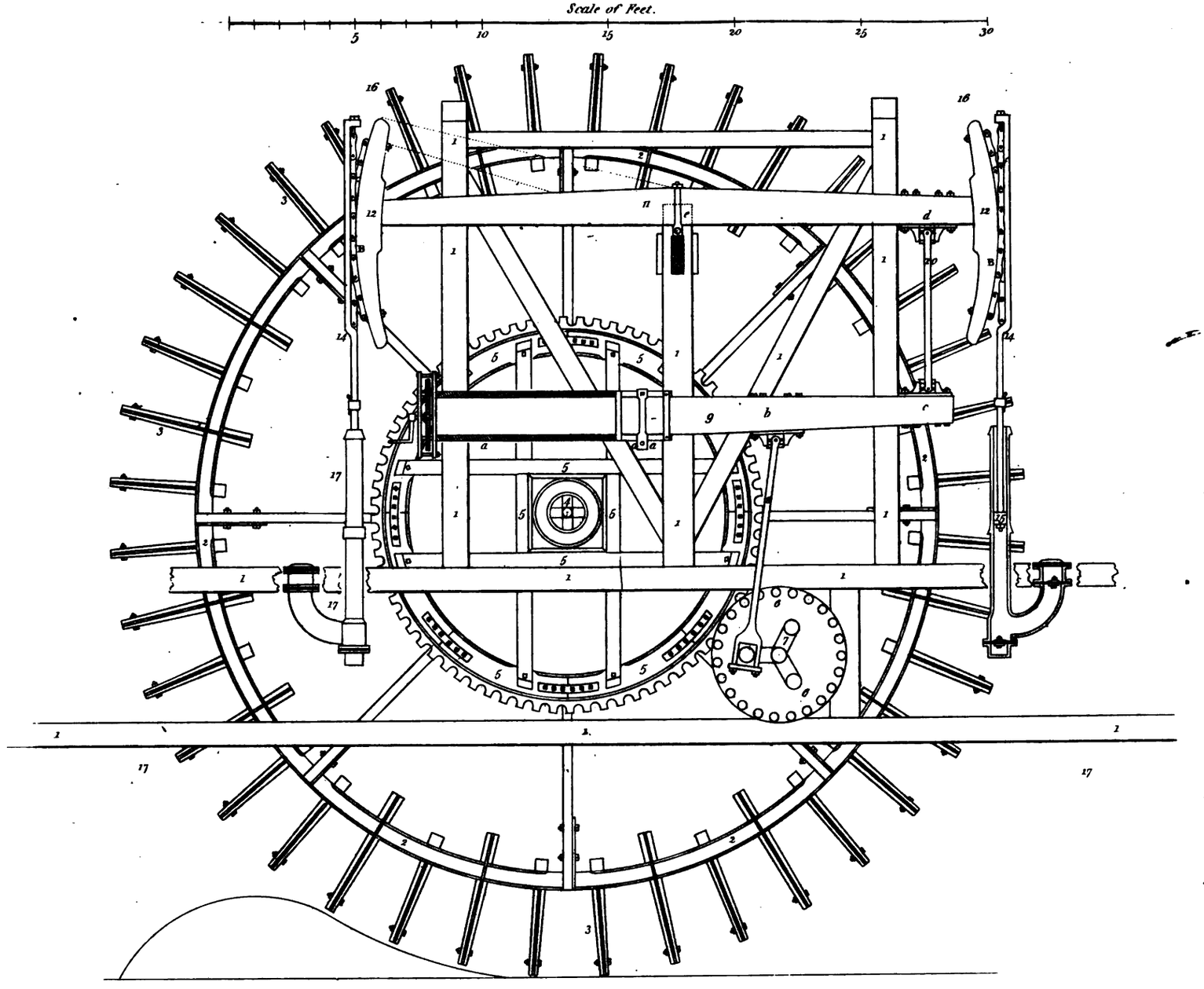
PLAN of the LOCK & SLUICE



PLAN of BRISTOL KEY with the PROJECTION of the SLUICES & CANAL for FLOATING the SHIPPING.

J. Farey delin.

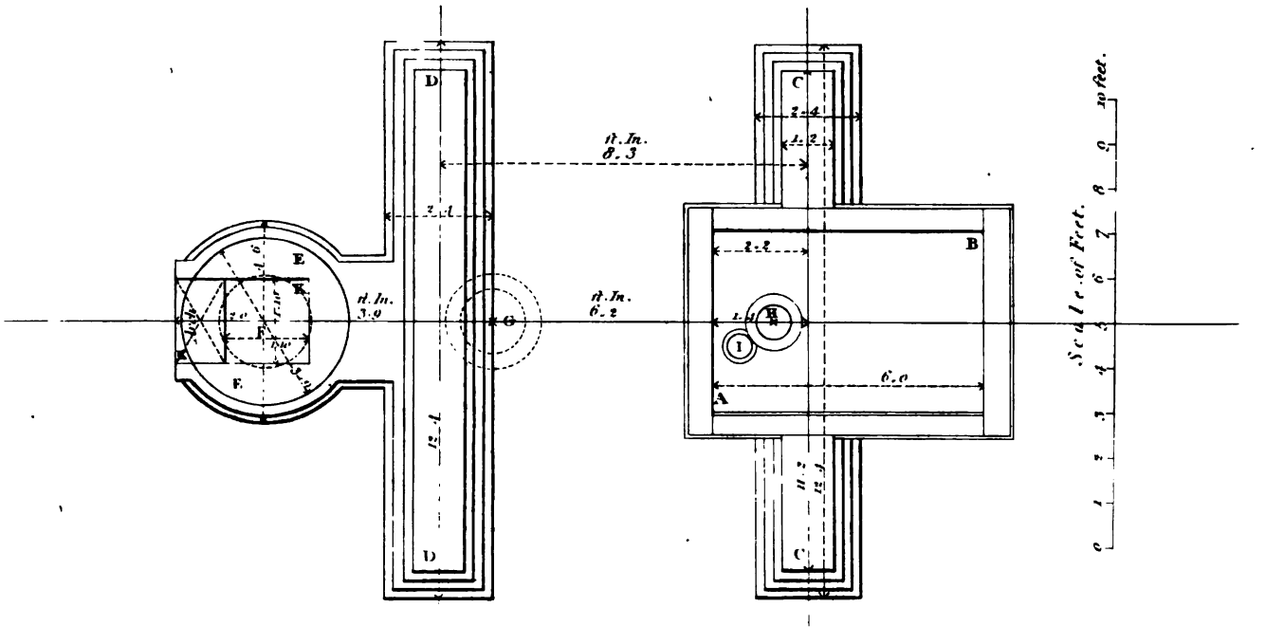
Design for a WATER ENGINE, communicated by Dr. Birch to Mr. Smeaton for his examination.



Engraved by Wilson Lowry

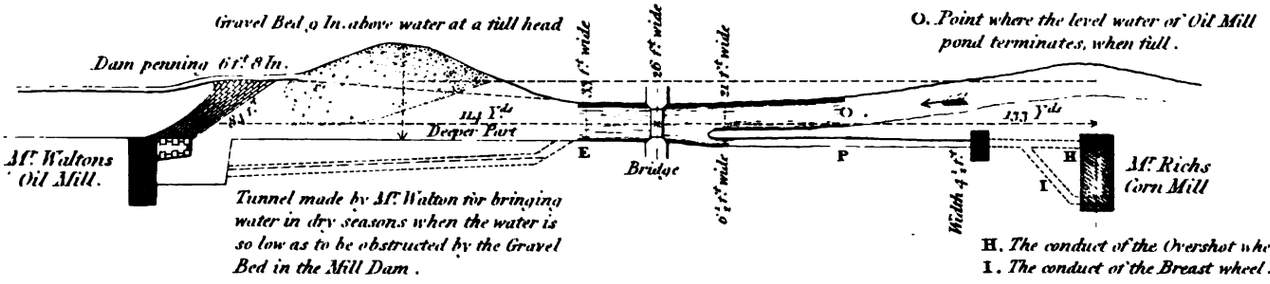
Ground Plan of the Portable Fire Engine.

Vol. 1. page 152.



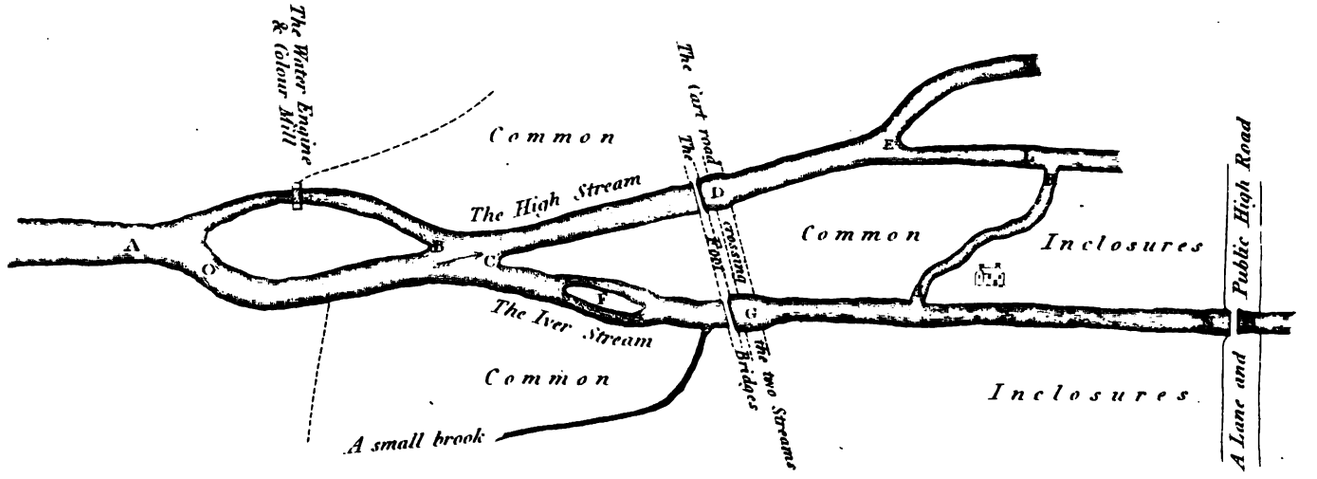
Vol. 1. page 163

Sketch of the disposition of Thurlston Mills.


Gravel Bed 9 In. above water at a full head
Dam penning 6 Ft. 8 In.
O. Point where the level water of Oil Mill pond terminates, when full.
Deeper Part
Mr. Waltons Oil Mill.
Bridge
Mr. Richs Corn Mill
Tunnel made by Mr. Walton for bringing water in dry seasons when the water is so low as to be obstructed by the Gravel Bed in the Mill Dam.
H. The conduct of the Overshot wheel.
I. The conduct of the Breast wheel.

SKETCH of the RIVER COLN.

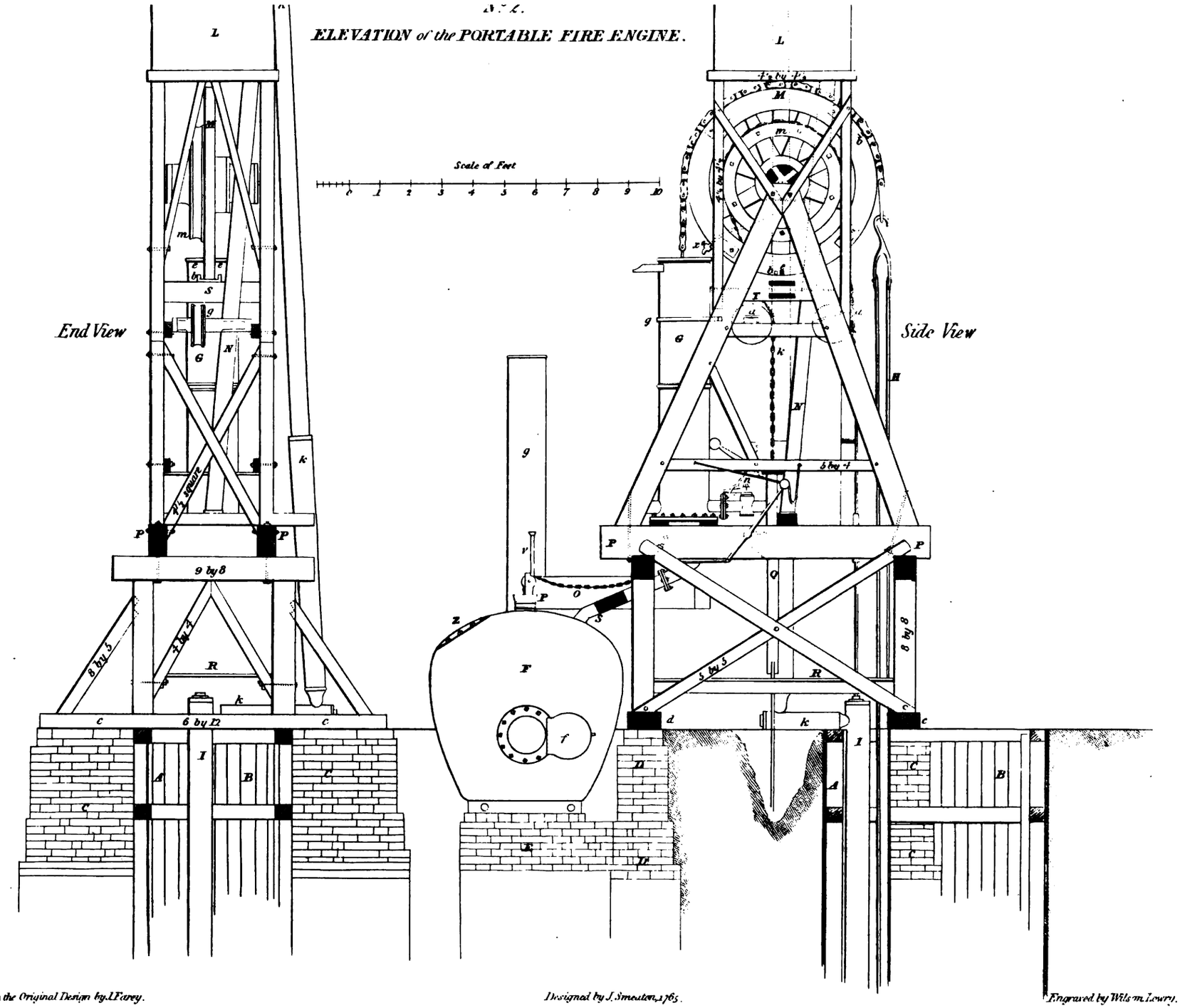
Vol. 1. page 214.



J. Farey Jun. del. Published as the Act directs, 1st Jan. by Longman, Hurst, Rees, Orme and Brown, Paternoster Row, London. W. Lowry sculp.

N° 2.

ELEVATION of the PORTABLE FIRE ENGINE.



Reduced from the Original Design by J. Farey.

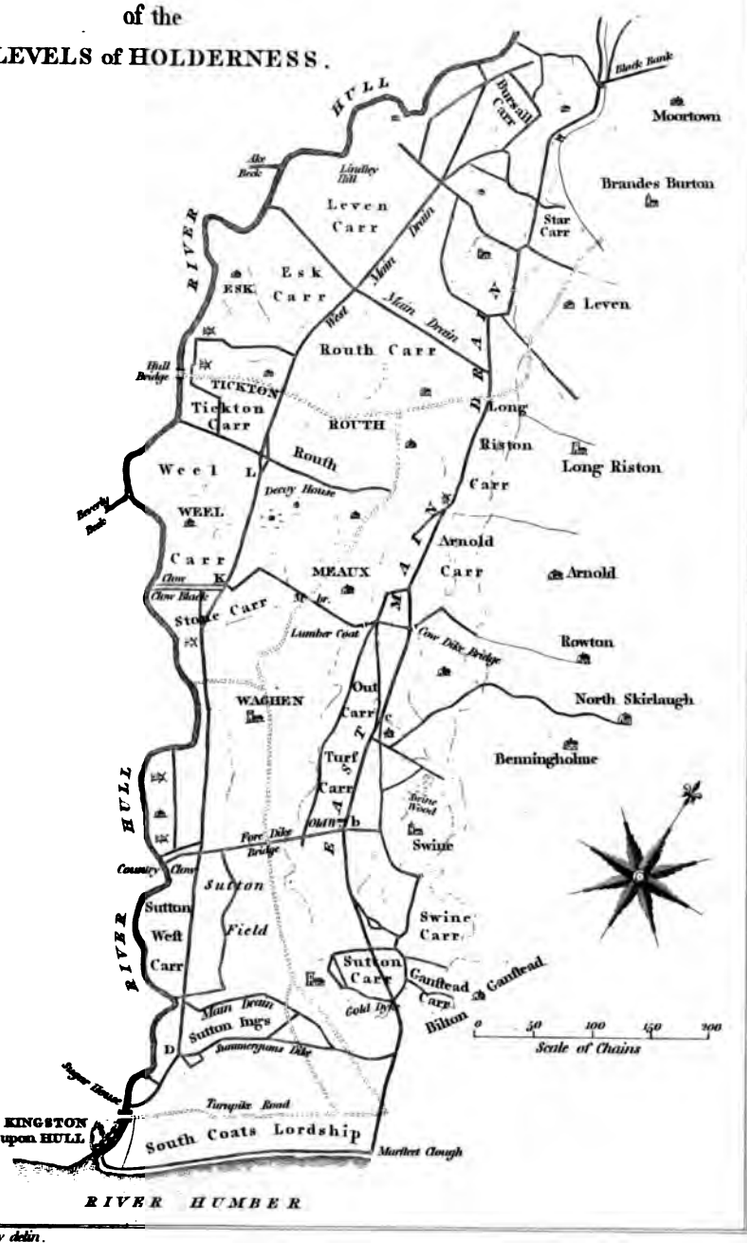
Designed by J. Smeaton, 1765.

Engraved by Wilm. Lowry.

Pl. 3.

Vol. I. p. 60.

A PLAN of the LEVELS of HOLDERNESS.

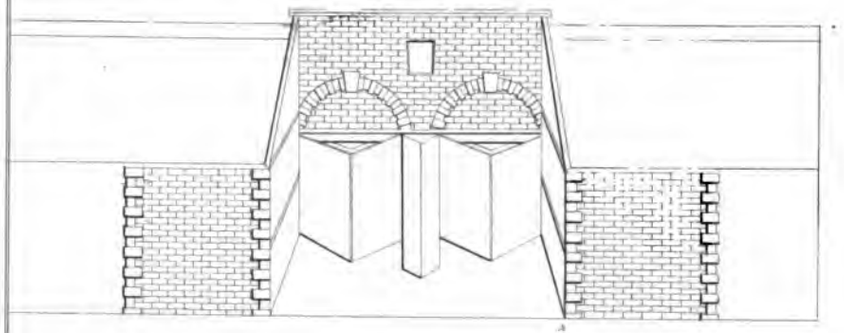


Farey delin.

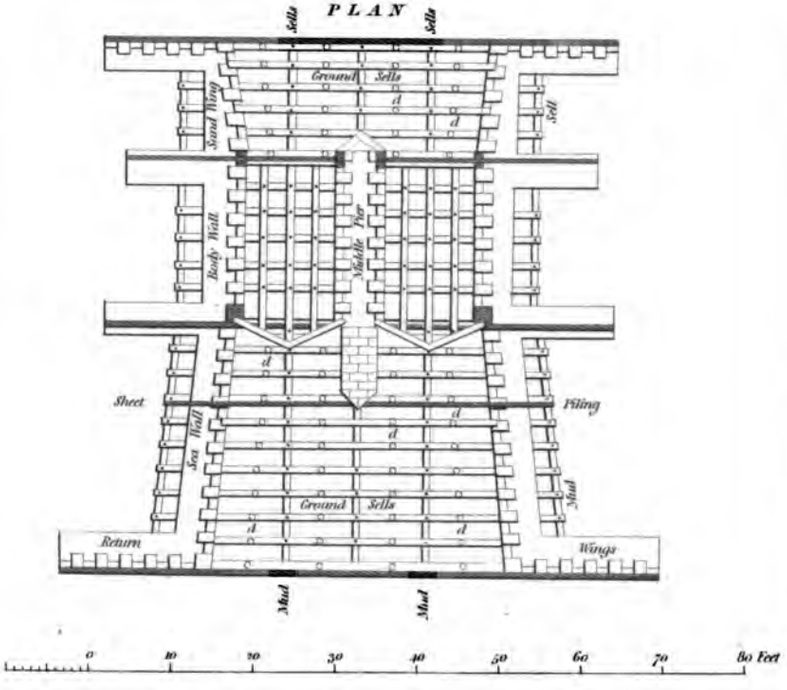
Vol. I. p. 64.

HOLDERNESS SEA SLUICE

ELEVATION SEAWARD



PLAN



W. Lowry sculp.

Published as the Act directs 1812, by Longman, Hurst, Rees, Orme and Brown, Paternoster Row, London.

DESIGN for a NEW BUCKET for FIRE ENGINES.

Fig. 4.

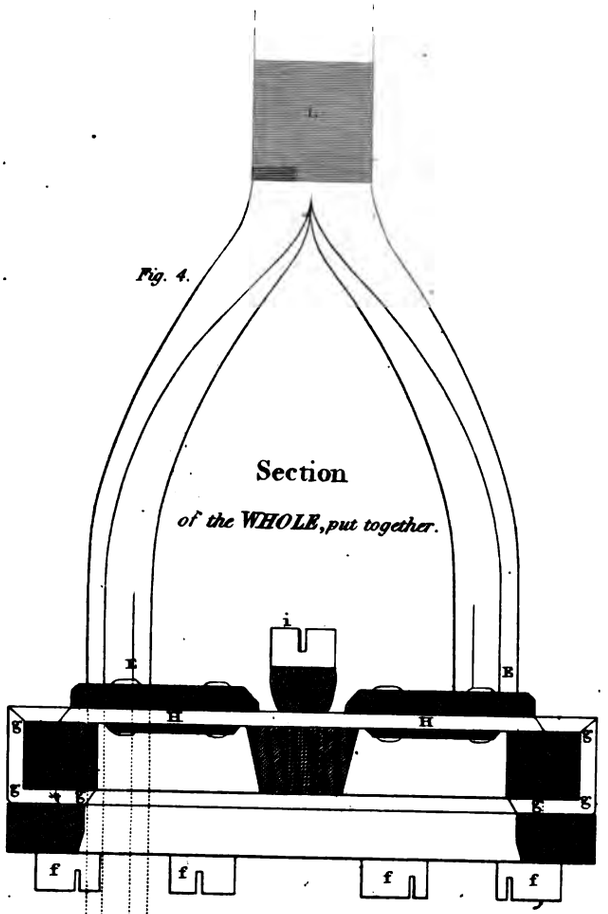


Fig. 2.

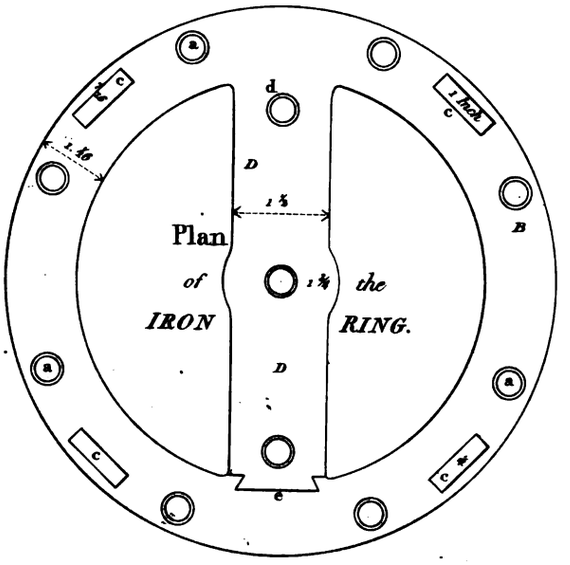


Fig. 3.

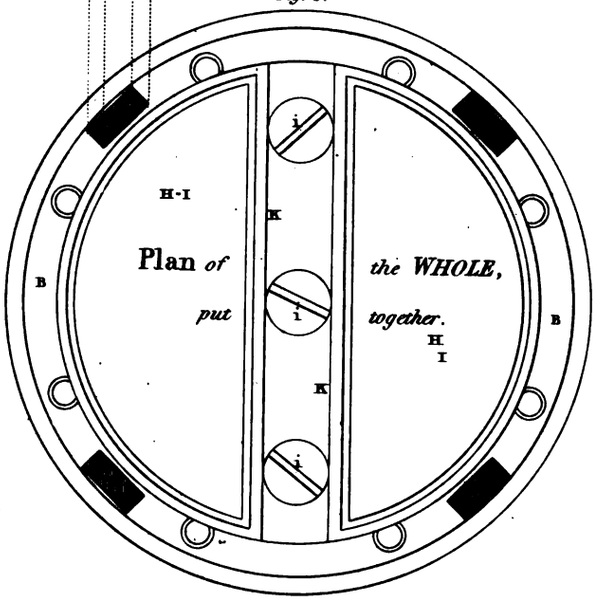
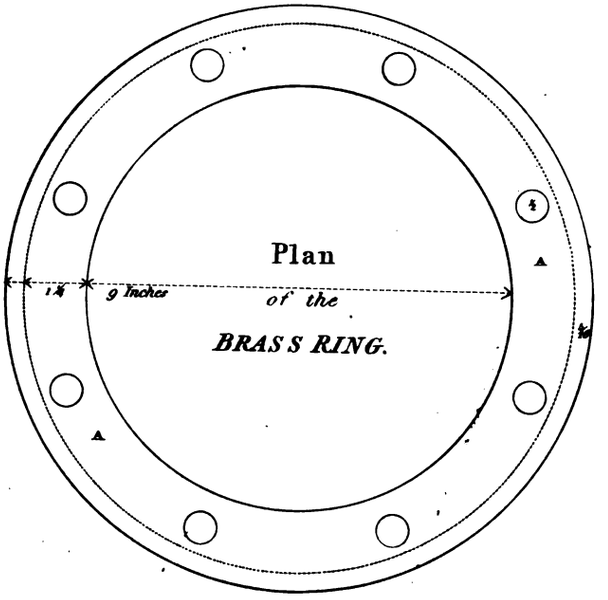
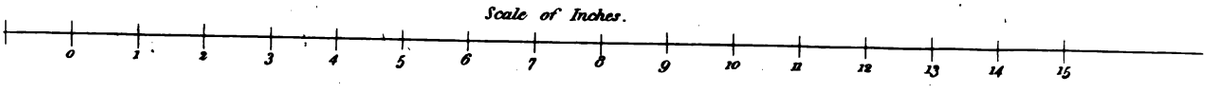


Fig. 1.



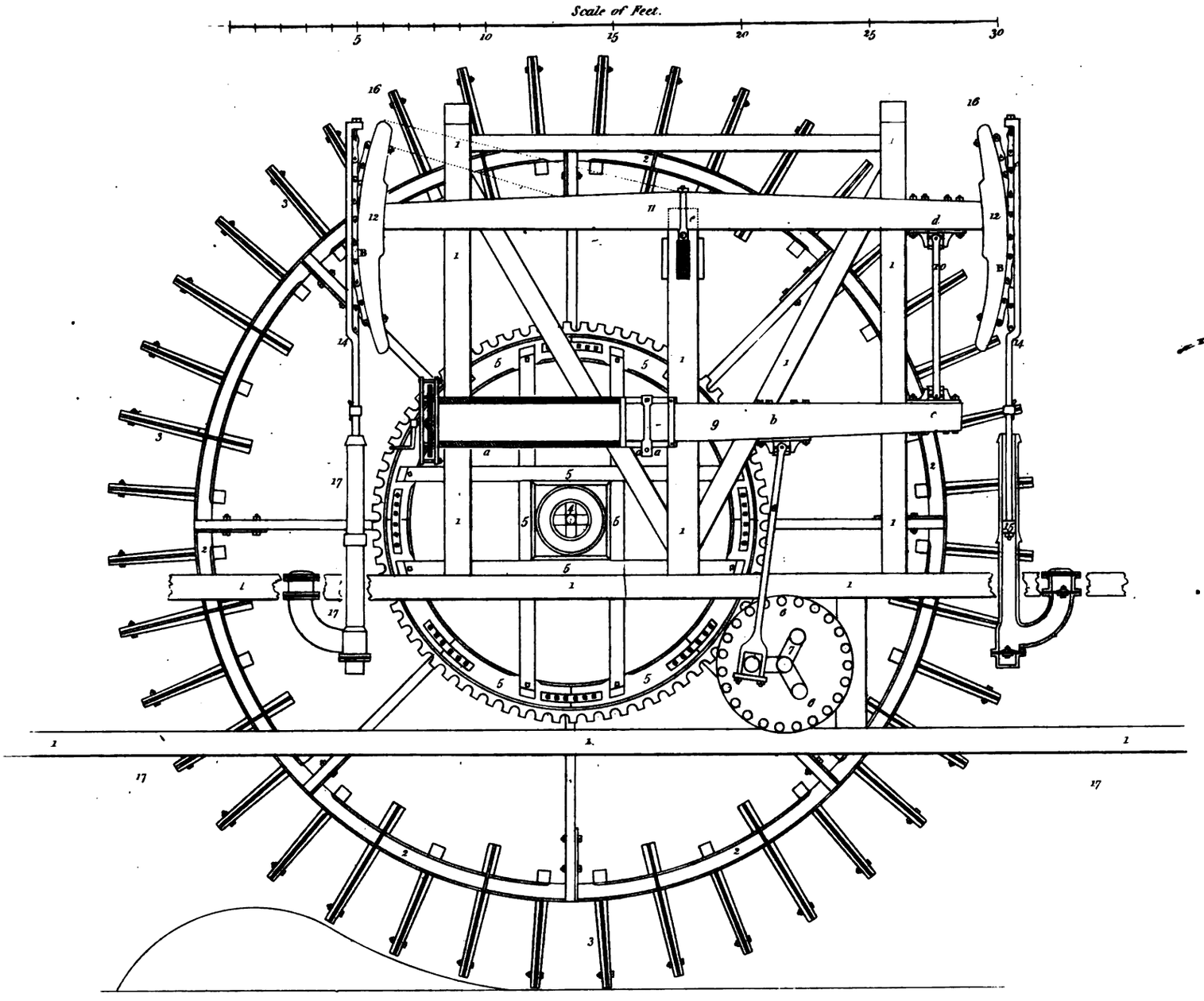
Scale of Inches.



London, Published by Longman, Hurst, Rees & Orme, 1810.

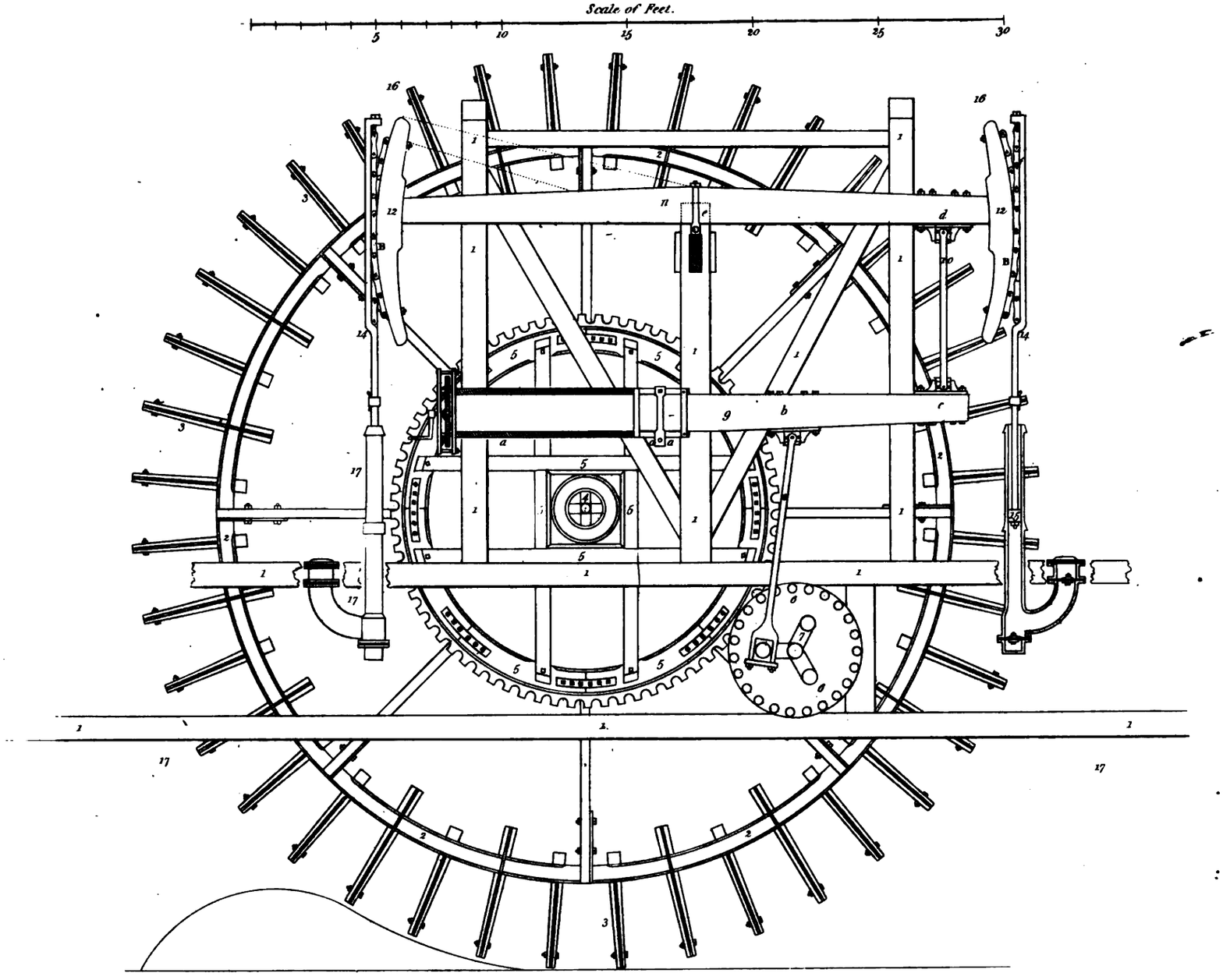
Engraved by Wilson Lowry.

Design for a WATER ENGINE, communicated by Dr. Birch to Mr. Smeaton for his examination.



Engraved by Wilson Lowry.

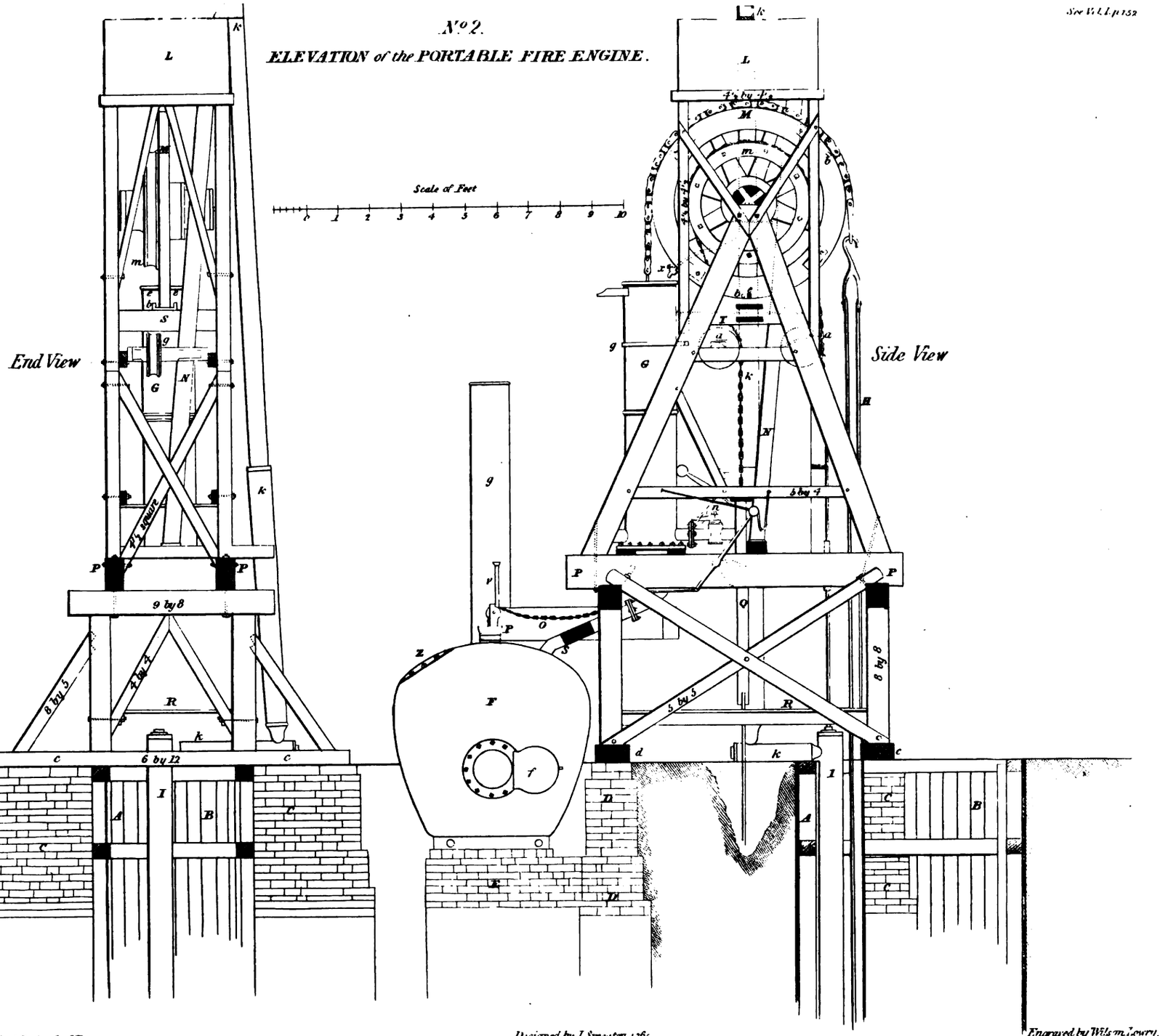
Design for a **WATER ENGINE**, *communicated by D^r^ Birch to M^r^ Smeaton for his examination.*



Engraved by Wilson Lowry

N°. 2.

ELEVATION of the PORTABLE FIRE ENGINE.



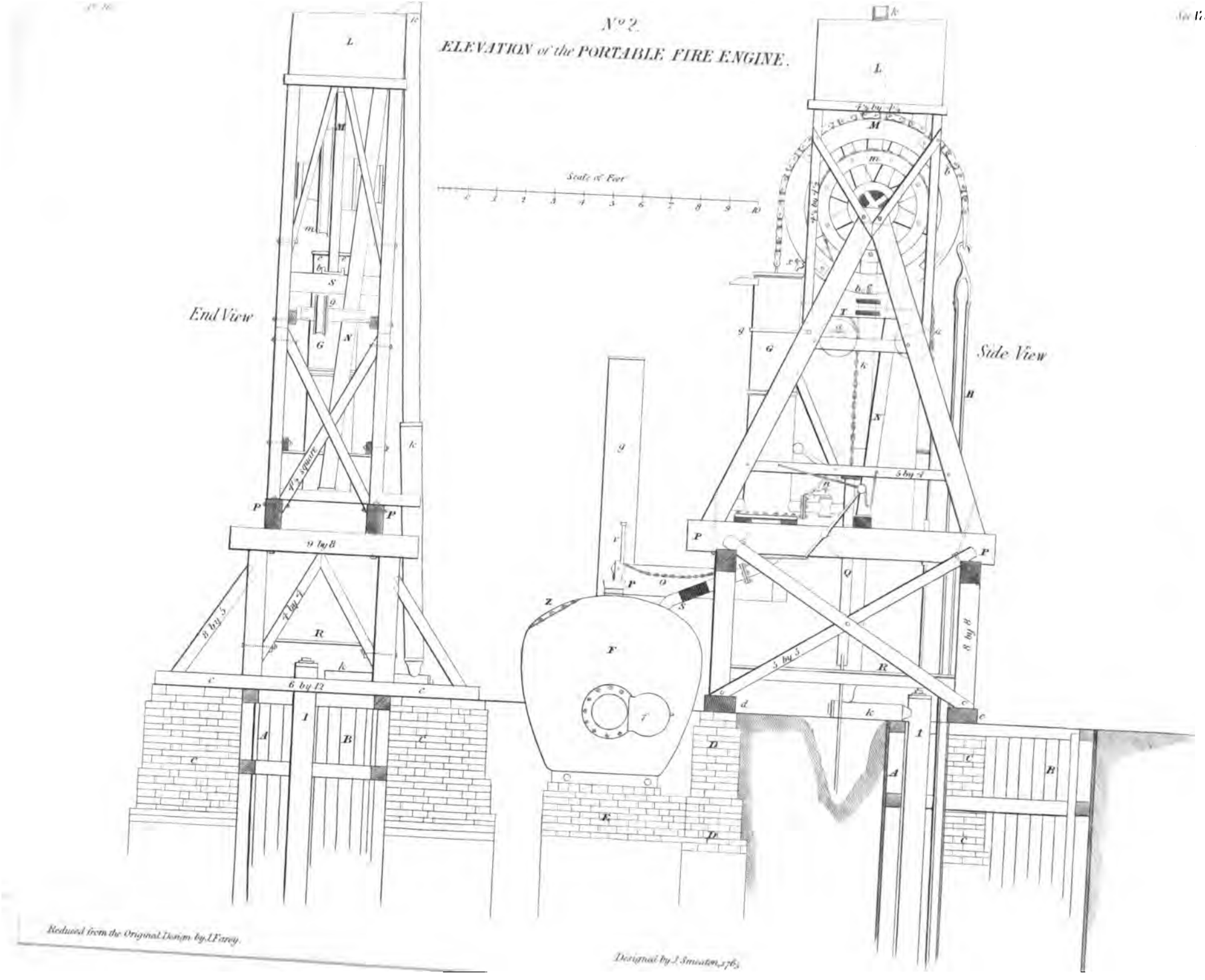
Reduced from the Original Design by I. Farey.

Designed by J. Smeaton, 1765.

Engraved by Wilson Lowry.

N°2.

ELEVATION of the PORTABLE FIRE ENGINE.



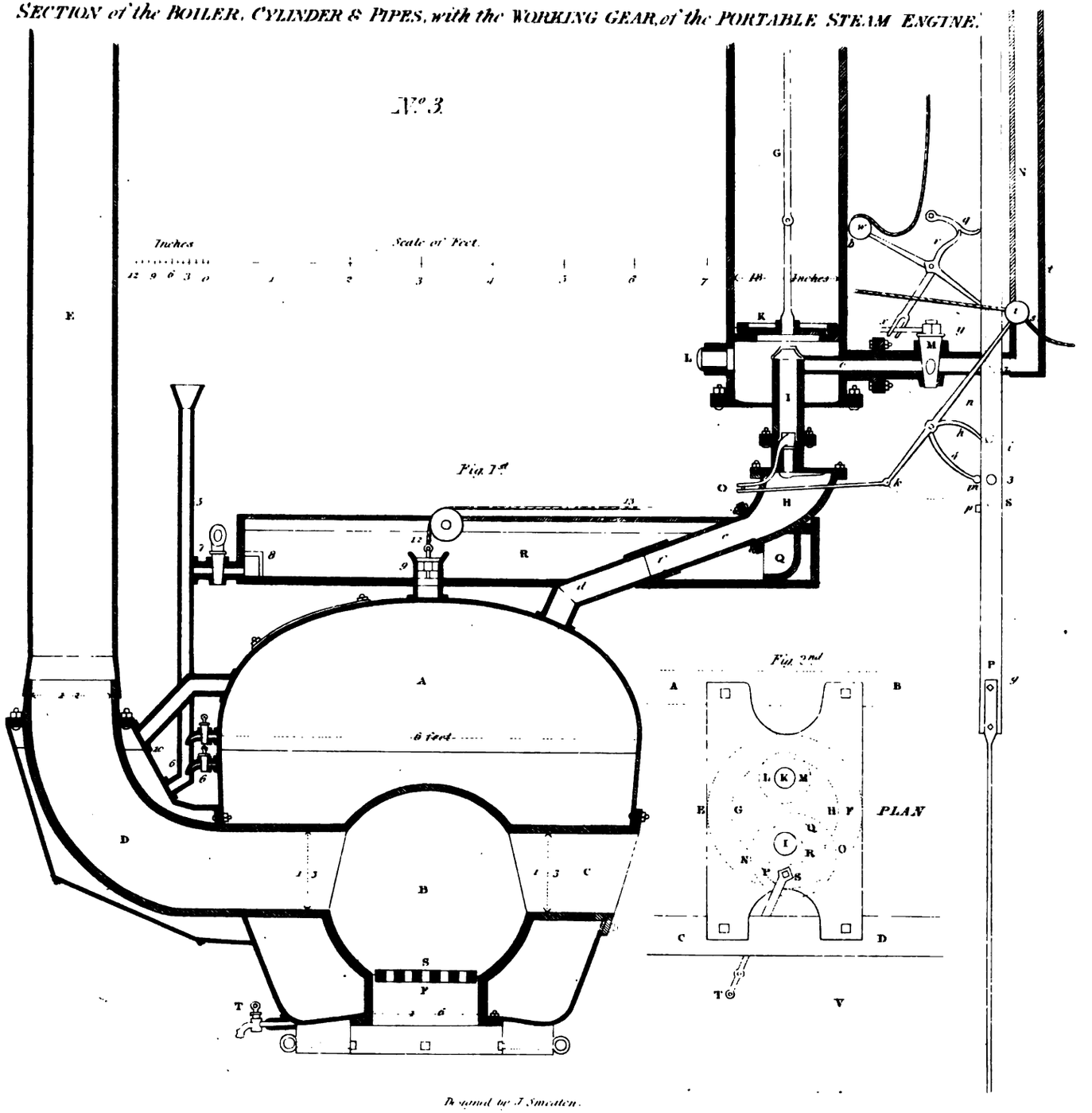
Reduced from the Original Design by J. Farey.

Designed by J. Smeaton 1763

SECTION of the BOILER, CYLINDER & PIPES, with the WORKING GEAR, of the PORTABLE STEAM ENGINE.

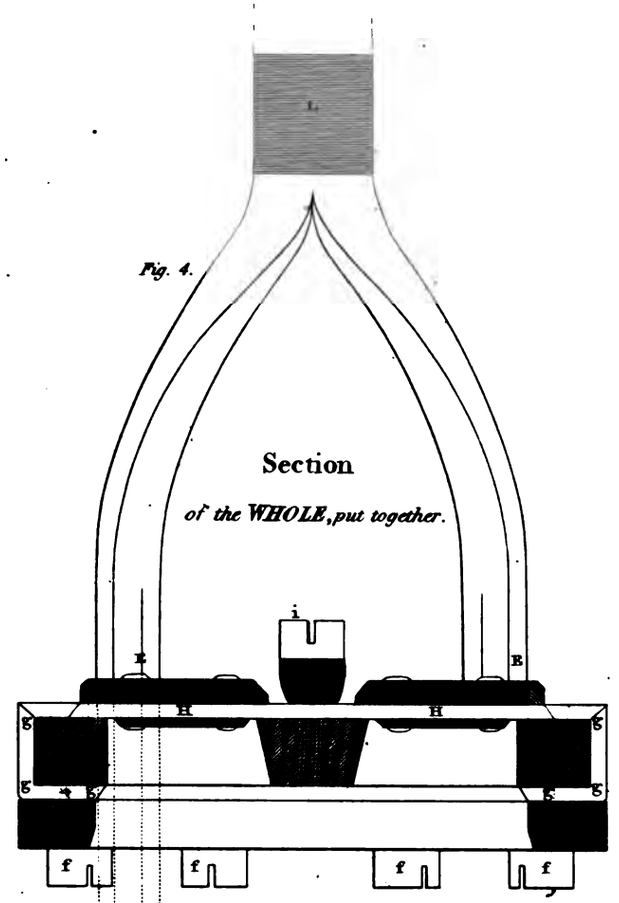
See Vol. I. p. 153.

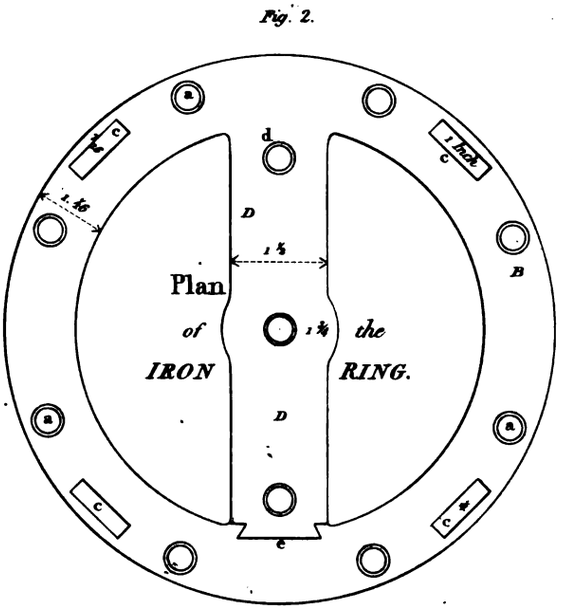
N°. 3.

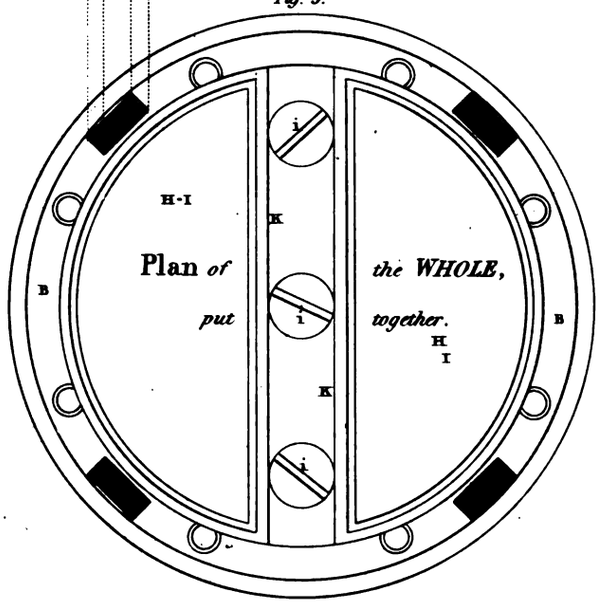


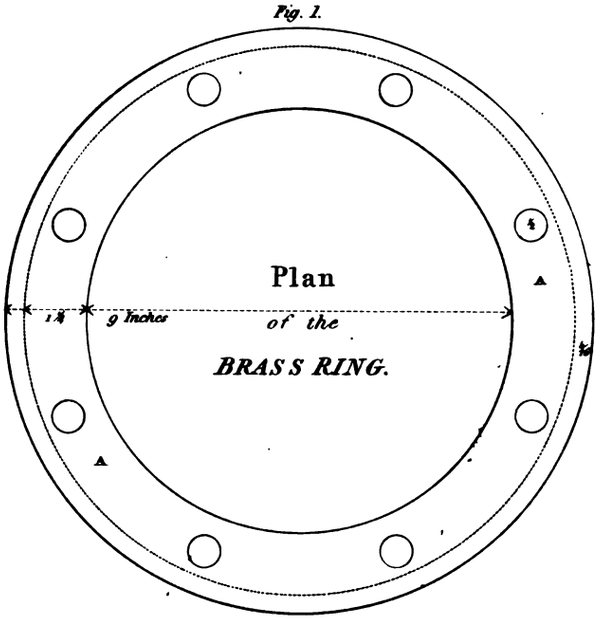
Designed by J. Smeaton.

DESIGN for a NEW BUCKET for FIRE ENGINES.

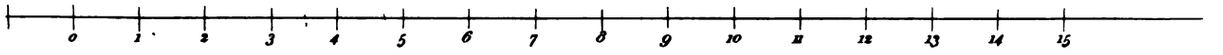








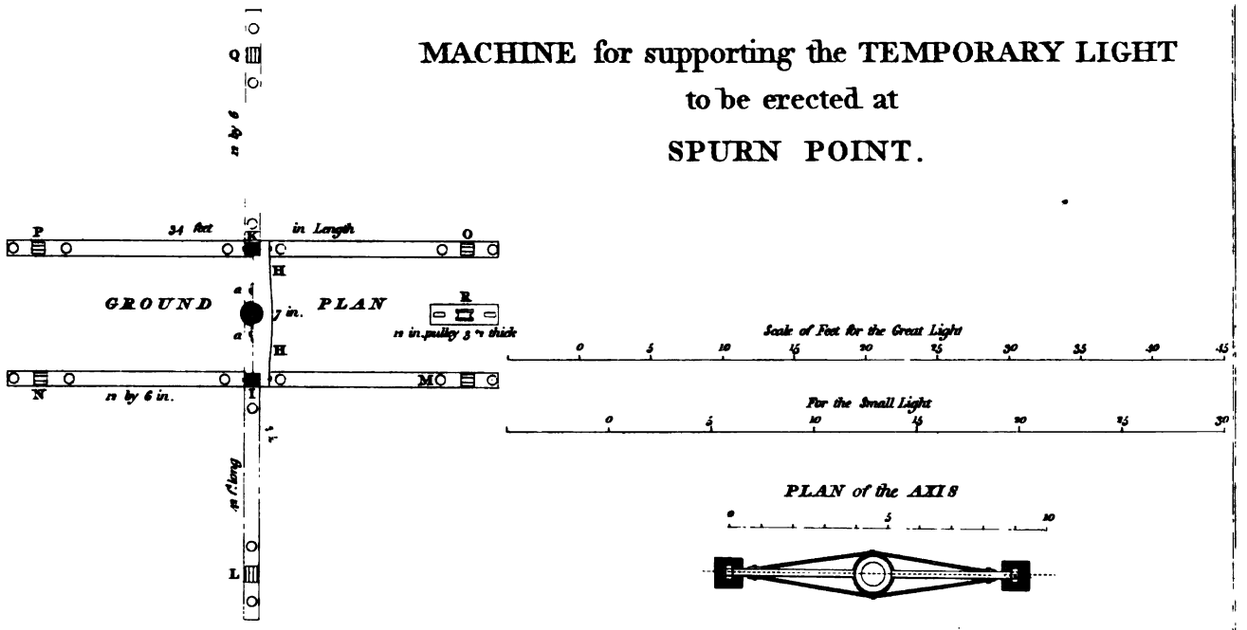
Scale of Inches.

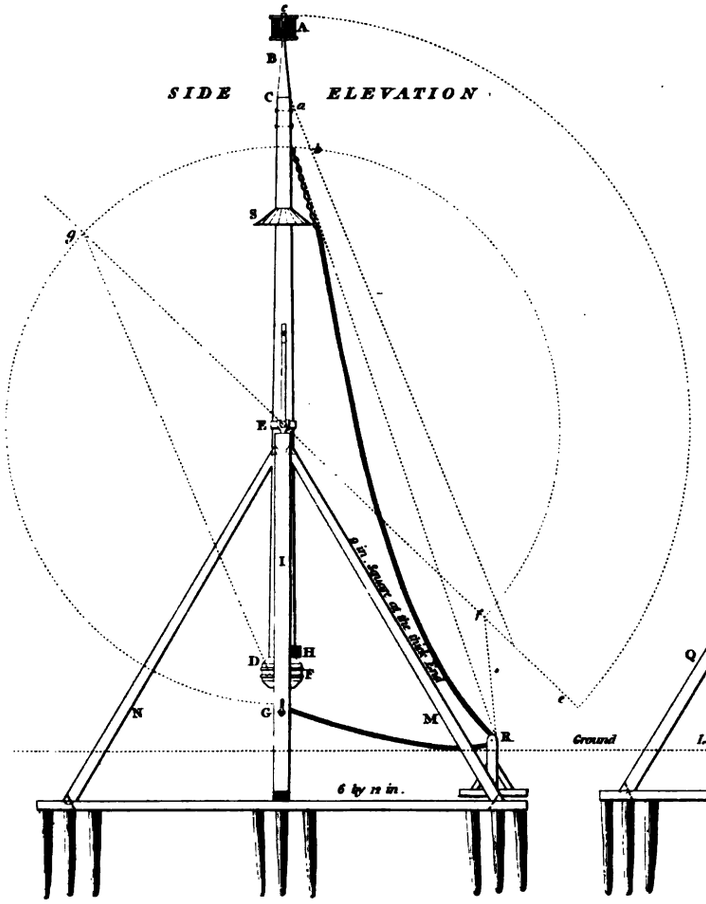


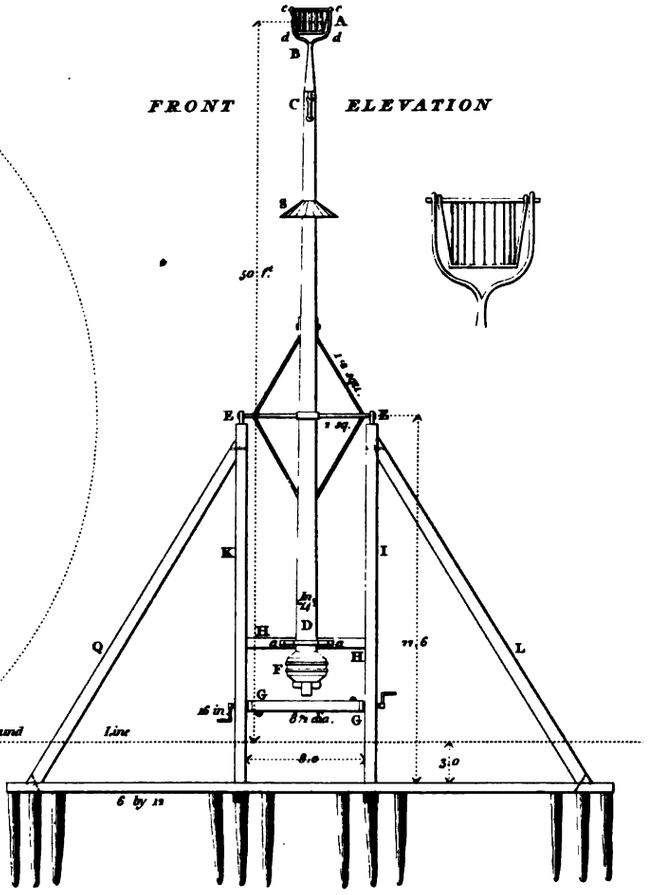
London, Published by Longman, Hurst, Rees & Orme, 1810.

Engraved by Wilson Lowry

MACHINE for supporting the TEMPORARY LIGHT to be erected at SPURN POINT.







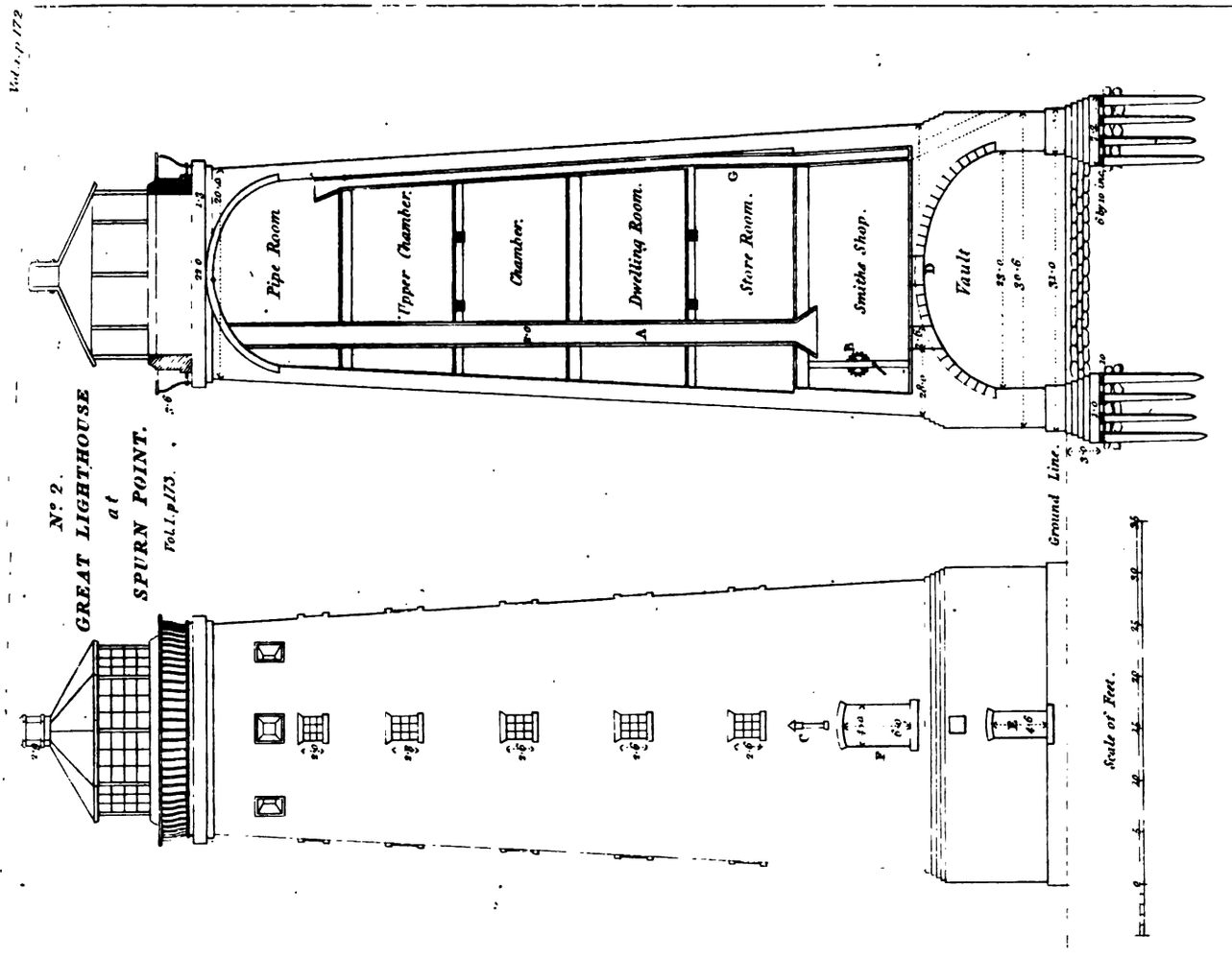
J. Farey, delin.

Published as the Act directs 28th by Longman Hurst Rees Orme and Brown Paternoster Row London.

W. Lowry sculp.

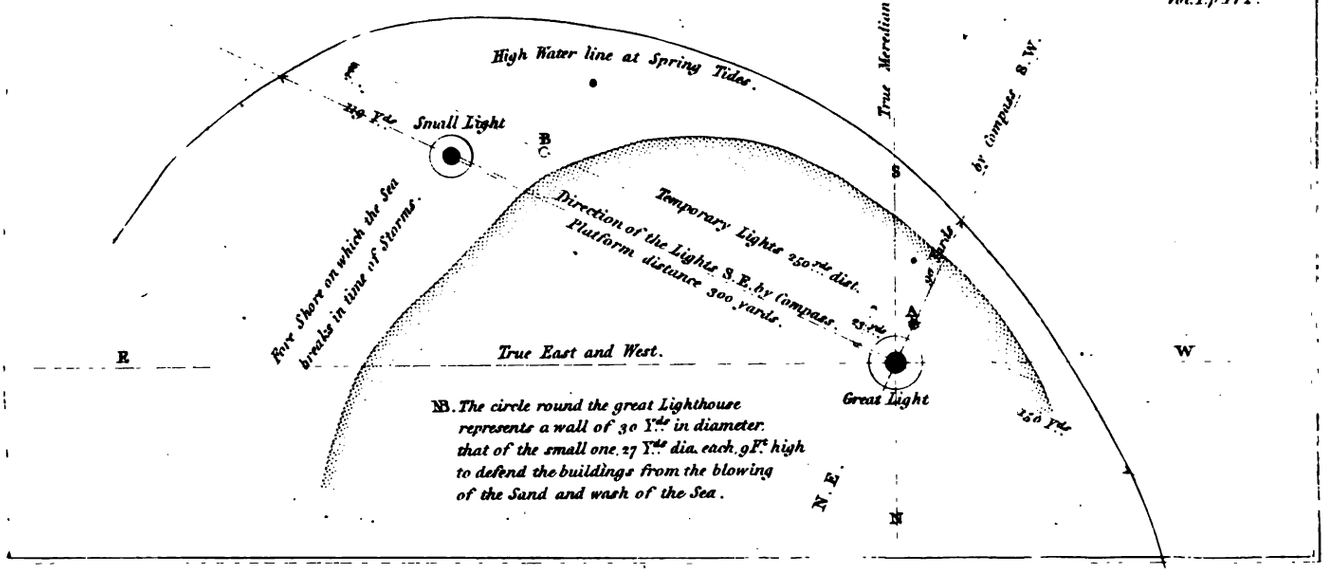
Vol. I. p. 172

Lowry sculp.



N.º 2. GREAT LIGHTHOUSE at SPURN POINT. Vol. I. p. 173.

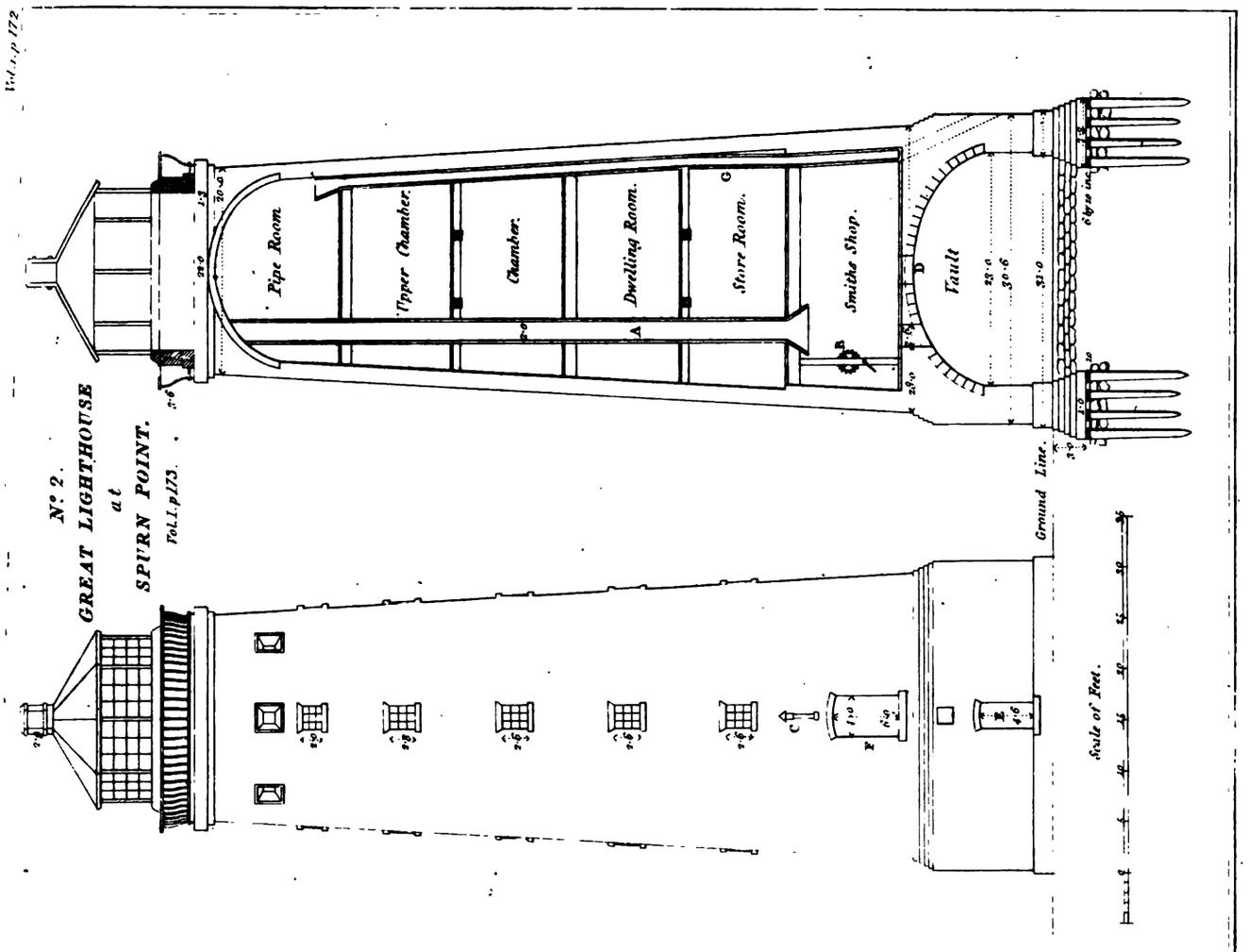
N.º 1. GENERAL PLAN of the Situation, Bearings, Distances &c. of the LIGHT HOUSES to be erected on SPURN POINT. Vol. I. p. 172.


High Water line at Spring Tides.
True Meridian.
by Compass S.W.
Small Light
Temporary Lights 250 Yds dist.
Direction of the Lights S.E. by Compass.
Platform distance 300 yards.
Fore Shore on which the Sea breaks in time of Storms.
True East and West.
Great Light
N.B. The circle round the great Lighthouse represents a wall of 30 Yds in diameter. that of the small one 27 Yds dia. each 9 Ft high to defend the buildings from the blowing of the Sand and wash of the Sea.
N. E.
S.
R
W

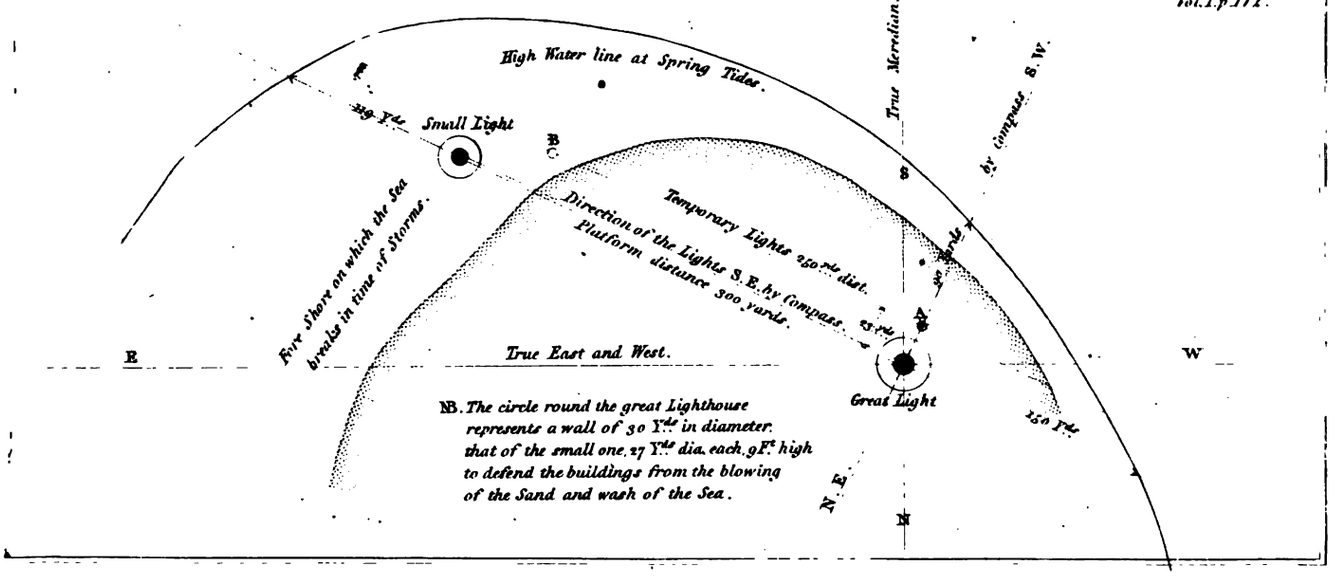
Pl. 14.

Published as the Act directs 1782, by Longman, Hurst, Rees, Orme and Brown, Paternoster Row London.

Earey delin.



N.º 1. GENERAL PLAN of the Situation, Bearings, Distances &c. of the LIGHT HOUSES to be erected on SPURN POINT
Vol. I. p 172.


High Water line at Spring Tides.
True Meridian.
by Compass S. W.
339 Fᵗˢ
Small Light
Temporary Lights 250 Yᵈˢ dist.
Direction of the Lights S. E. by Compass.
Platform distance 300 yards.
Fore Shore on which the Sea breaks in time of Storms.
True East and West.
Great Light
250 Fᵗˢ
NB. The circle round the great Lighthouse represents a wall of 30 Yᵈˢ in diameter. that of the small one, 27 Yᵈˢ dia. each, 9Fᵗ high to defend the buildings from the blowing of the Sand and wash of the Sea.

Pl. 14.

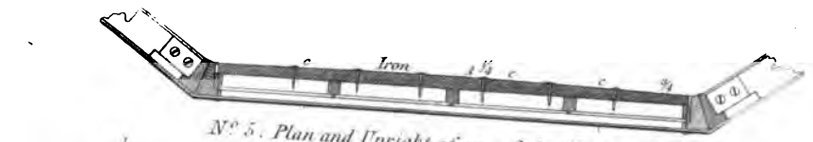
Lowry sculp.

Published as the Act directs, 1832, by Longman, Hurst, Rees, Orme, and Brown, Paternoster Row London.

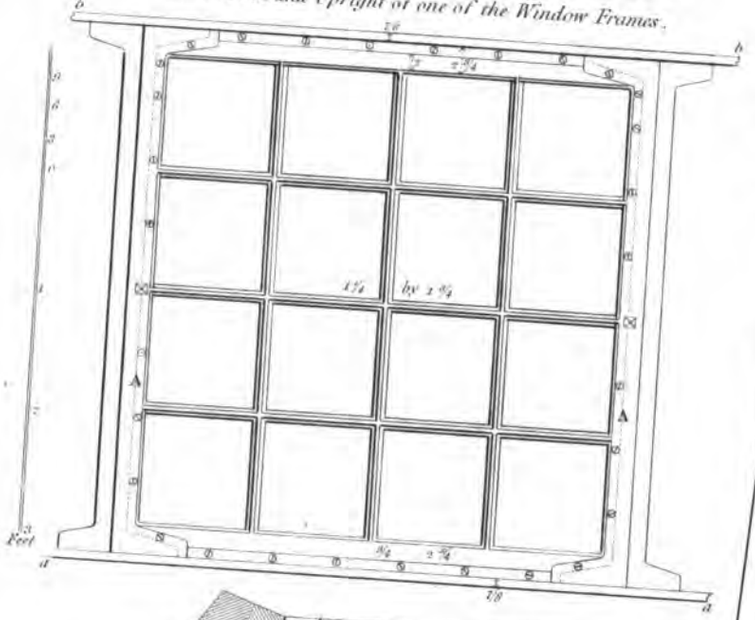
Eury delin.

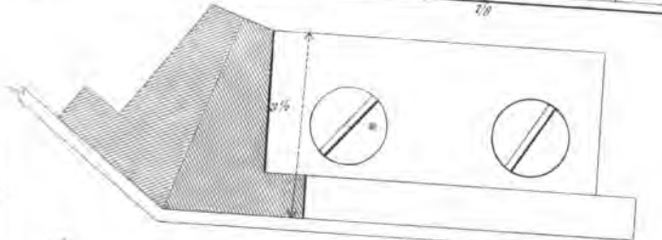
DESIGN FOR THE SMALL LIGHT HOUSE AT SPURN POINT.

Vol. I. p. 184

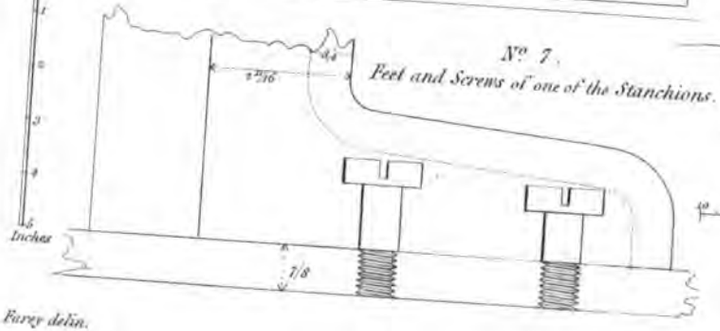


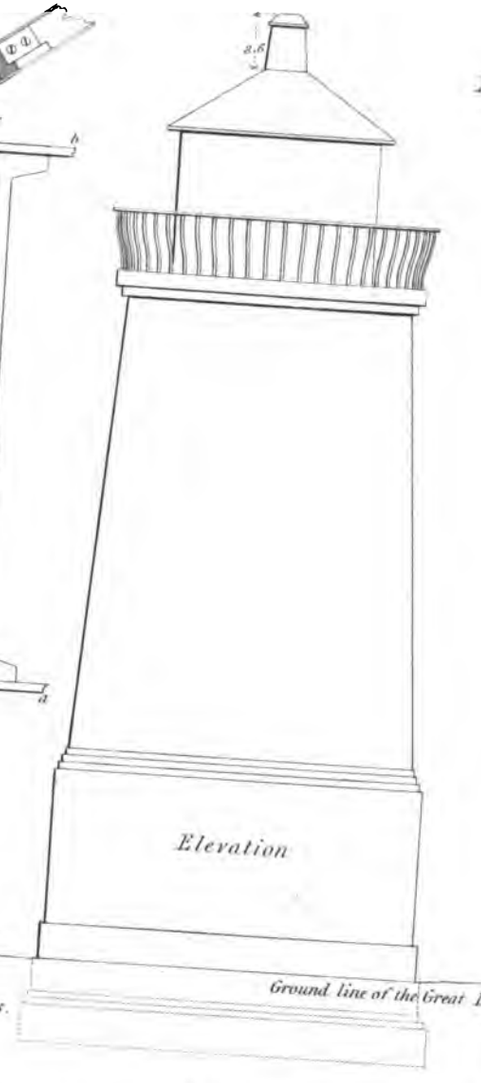
No. 5. Plan and Upright of one of the Window Frames.



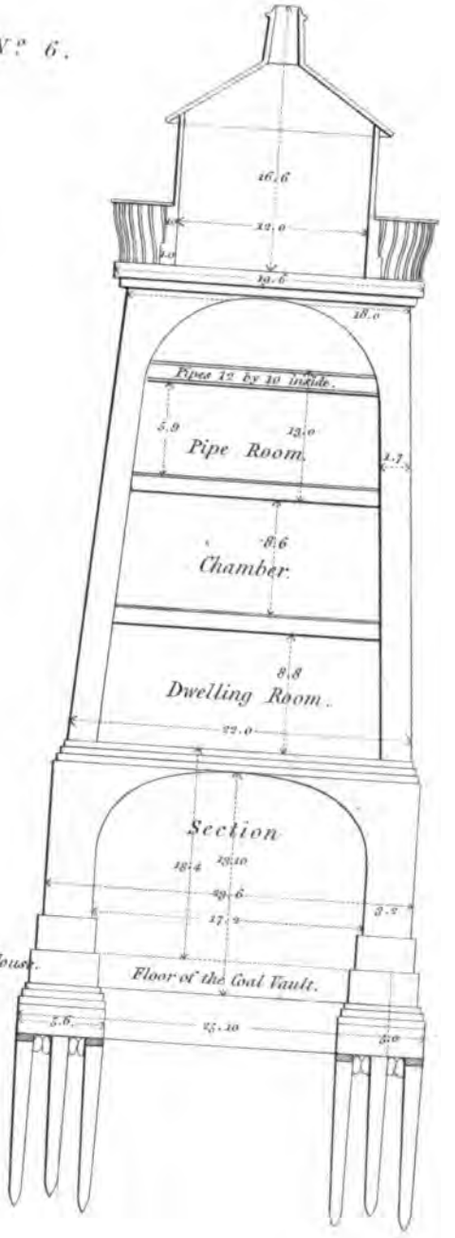


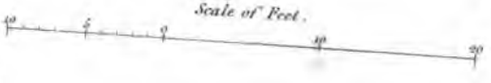
No. 7.
Feet and Screws of one of the Stanchions.





No. 6.



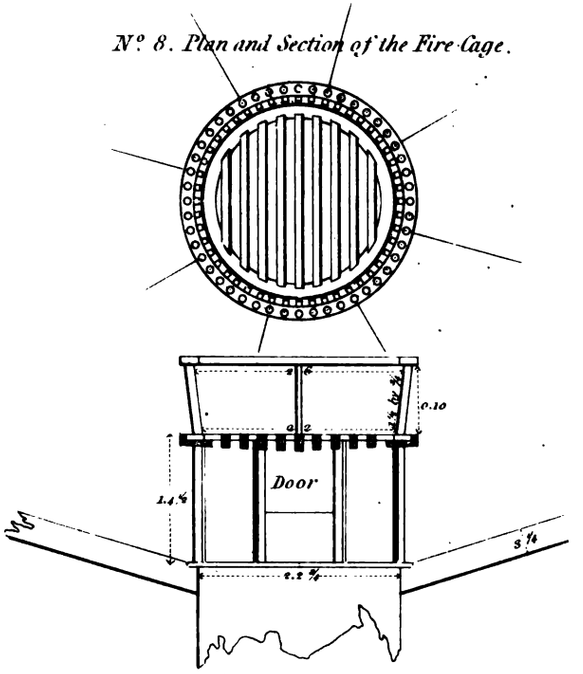


Farey delin.

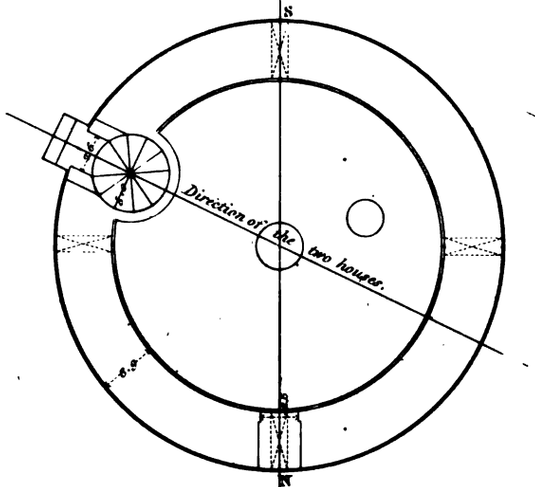
Published as the Act directs, 1st Nov. by Longman, Hurst, Rees, Orme and Brown, Paternoster Row London.

SMALL LIGHT HOUSE AT SPURN POINT.

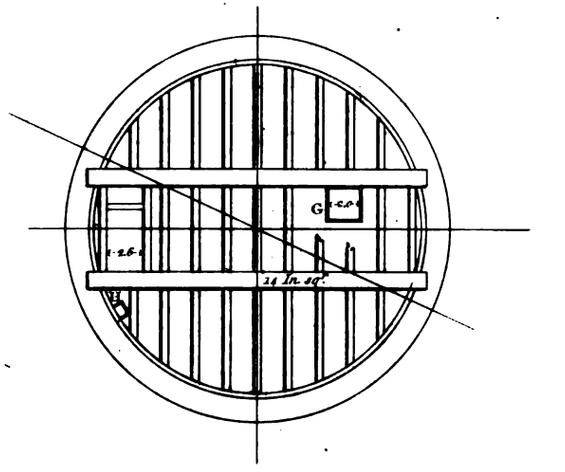
N°. 8. Plan and Section of the Fire Cage.



N°. 10. Basement Story.

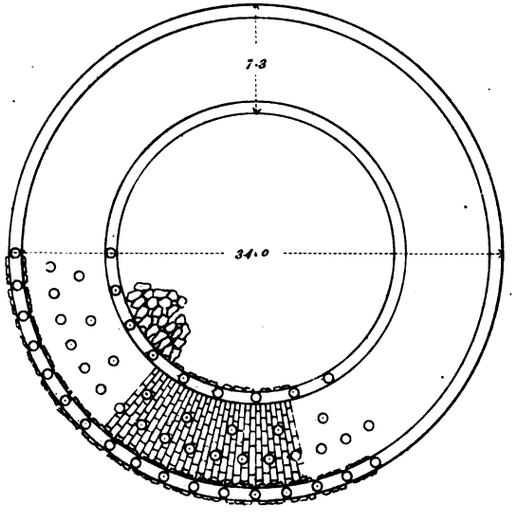


N°. 12. Store Room Floor.

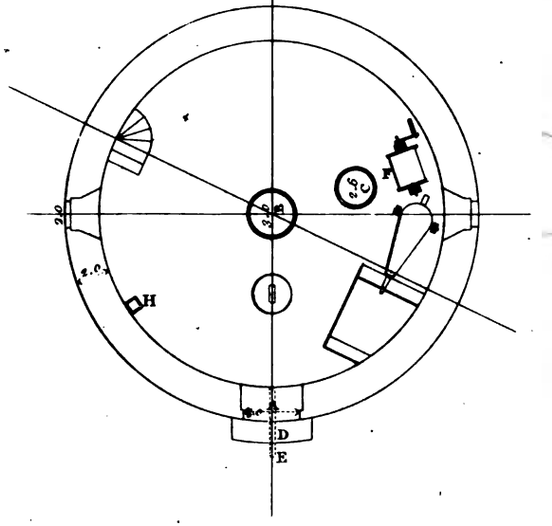


Scale of Feet.

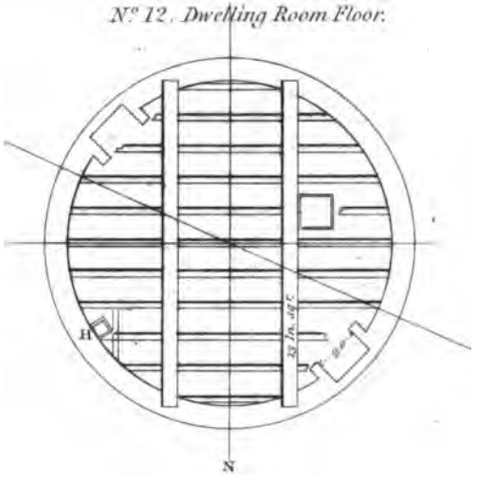
N°. 9. Ground Plan.



N°. 11. Smiths Shop Floor.



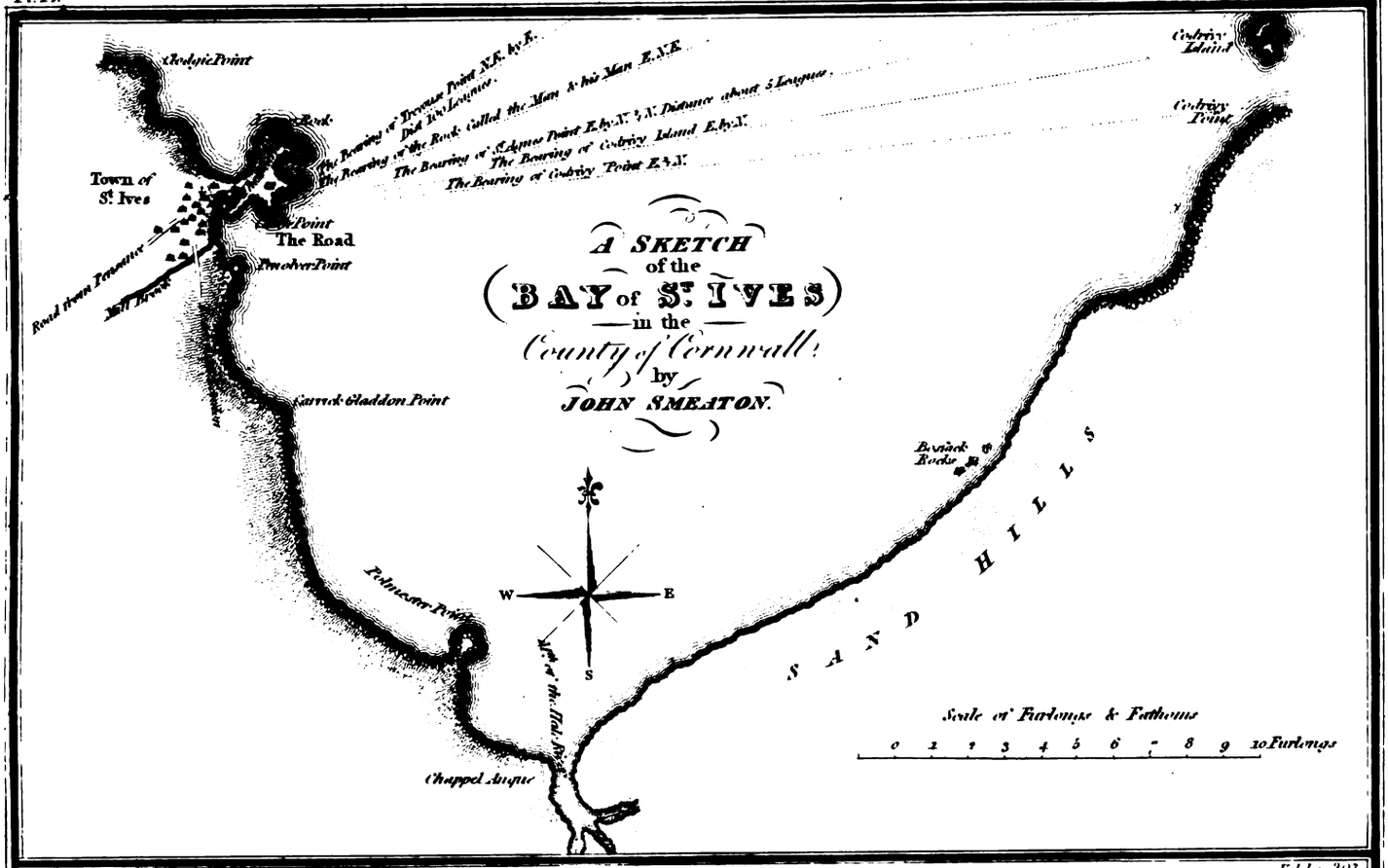
N°. 12. Dwelling Room Floor.



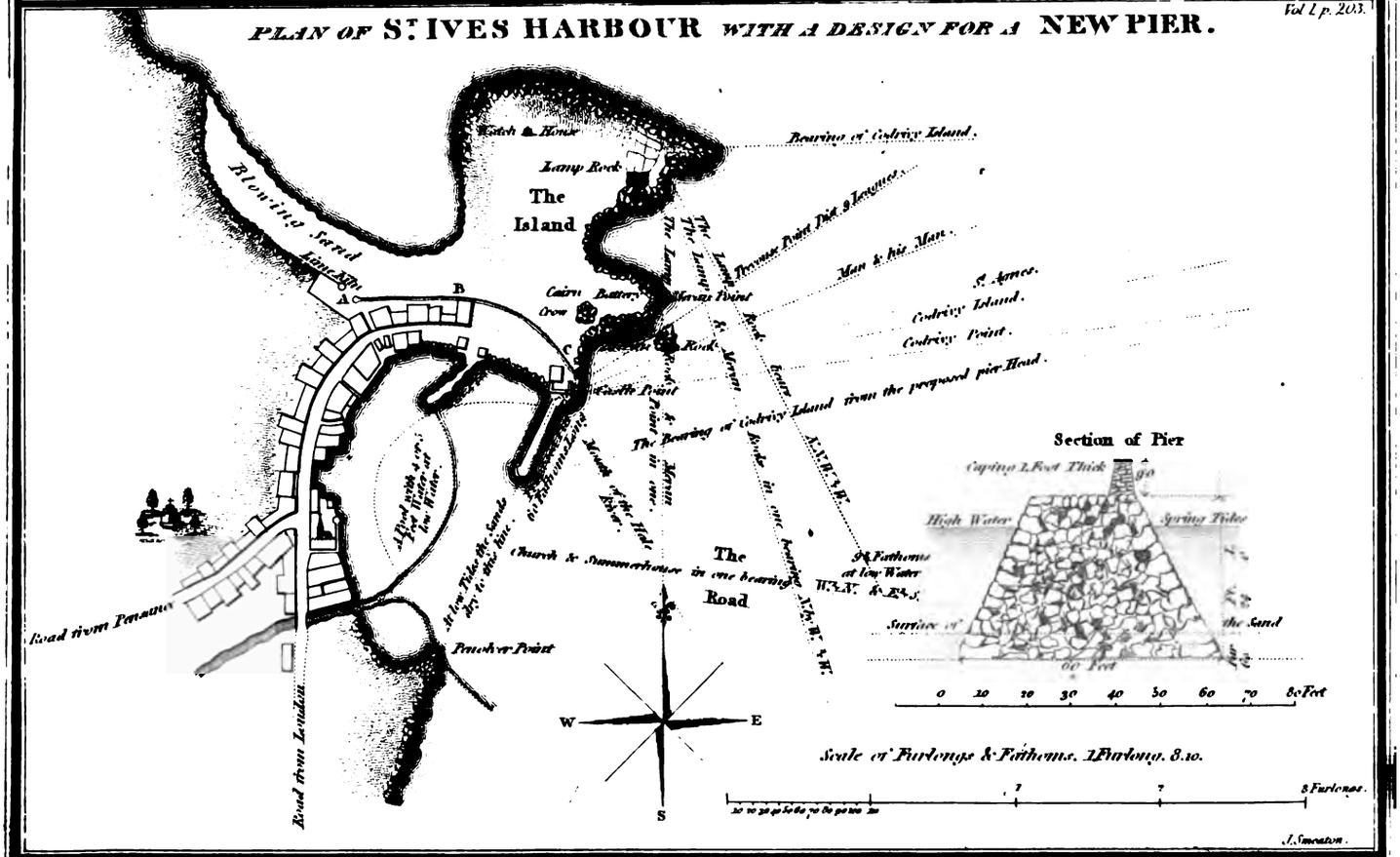
Farey delin.

Published as the Act directs, 1812, by Longman, Hurst, Rees, Orme and Brown, Paternoster Row, London.

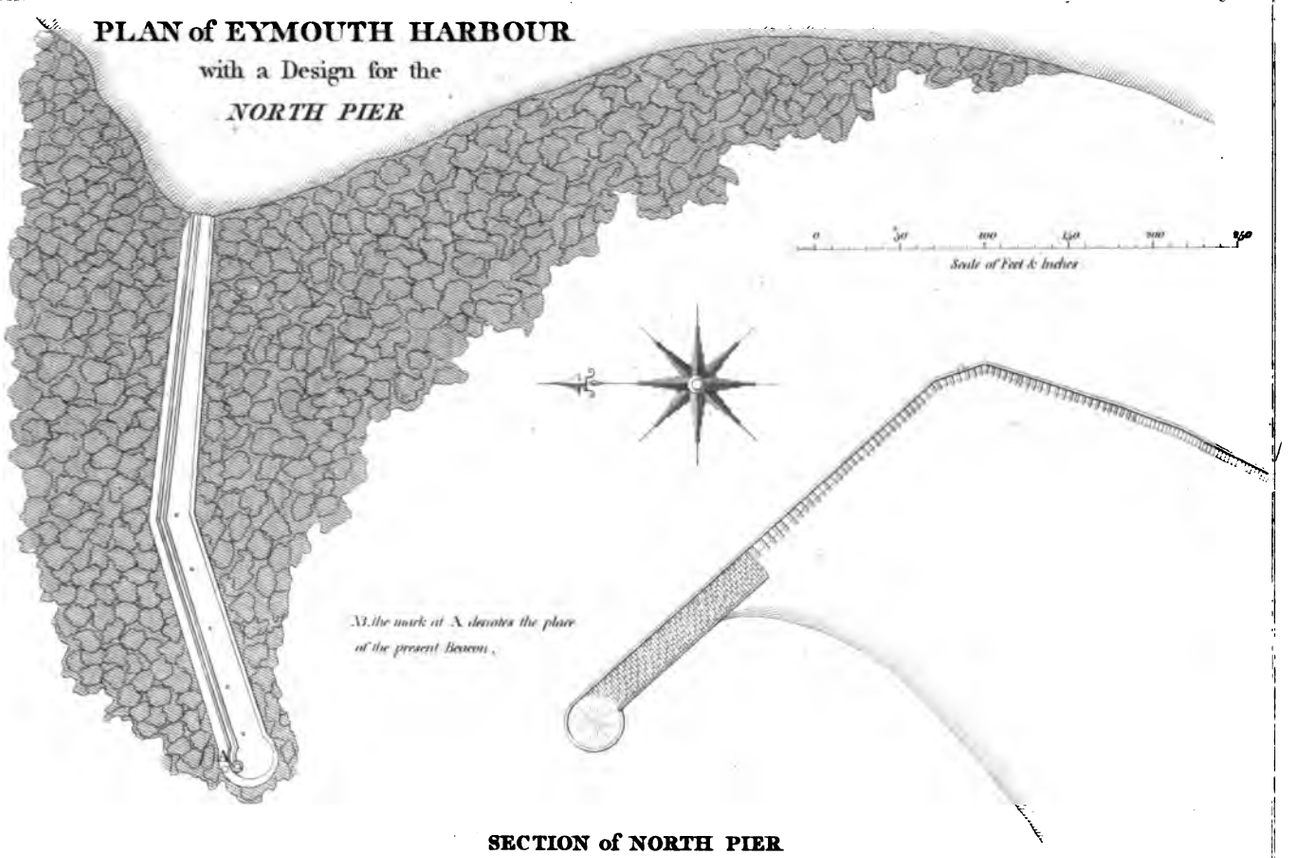
Lowry sculp.



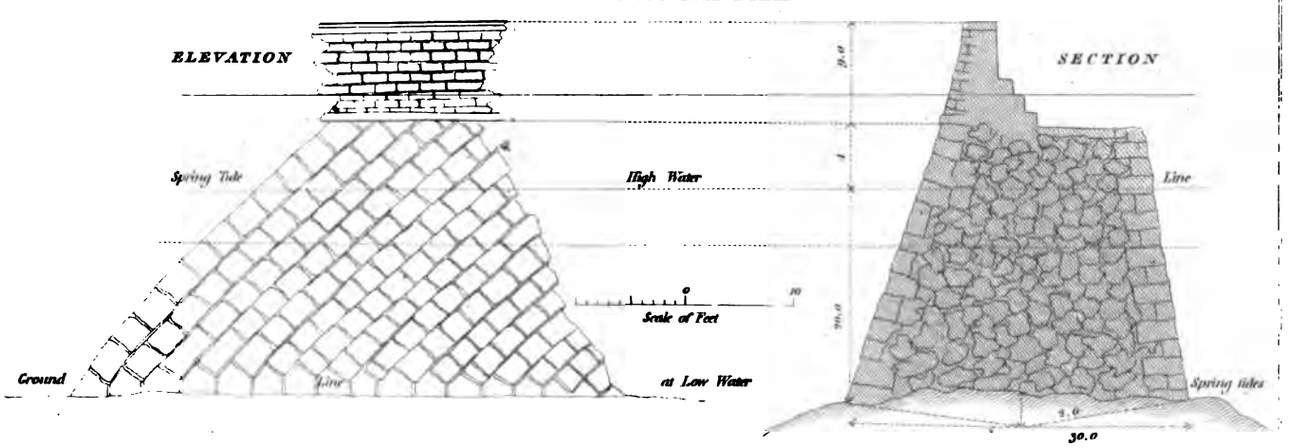
PLAN OF ST IVES HARBOUR WITH A DESIGN FOR A NEW PIER.



PLAN of EYMOUTH HARBOUR
with a Design for the
NORTH PIER

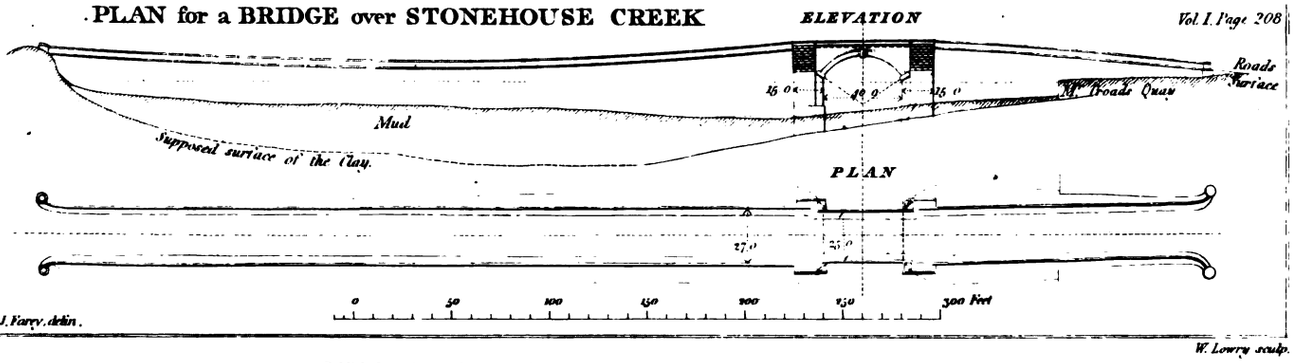


SECTION of NORTH PIER



PLAN for a BRIDGE over STONEHOUSE CREEK

Vol. I. Page 208

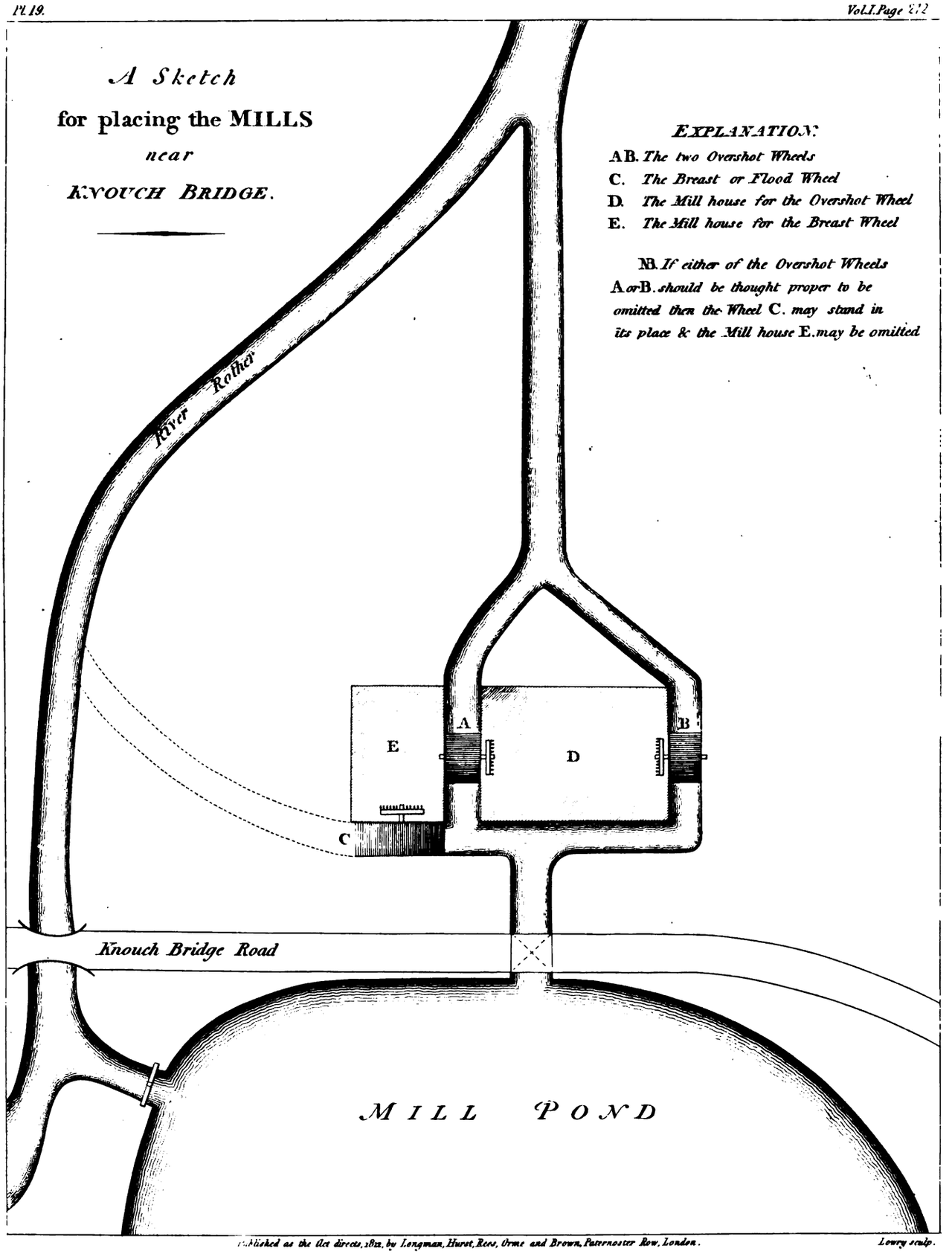


J. Farey. delin.

W. Lowry sculp.

Published as the Act directs 1812. by Longman, Hurst, Rees, Orme and Brown, Paternoster Row, London.

A Sketch
for placing the MILLS
near
KNOUCH BRIDGE.

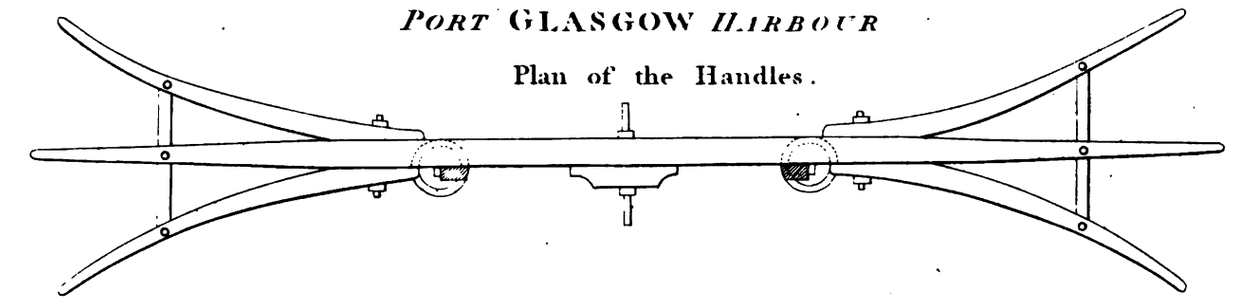

EXPLANATION.
AB. The two Overshot Wheels
C. The Breast or Flood Wheel
D. The Mill house for the Overshot Wheel
E. The Mill house for the Breast Wheel
NB. If either of the Overshot Wheels A or B. should be thought proper to be omitted then the Wheel C. may stand in its place & the Mill house E. may be omitted
River Rother
A
B
E
D
C
Knouch Bridge Road
MILL POND

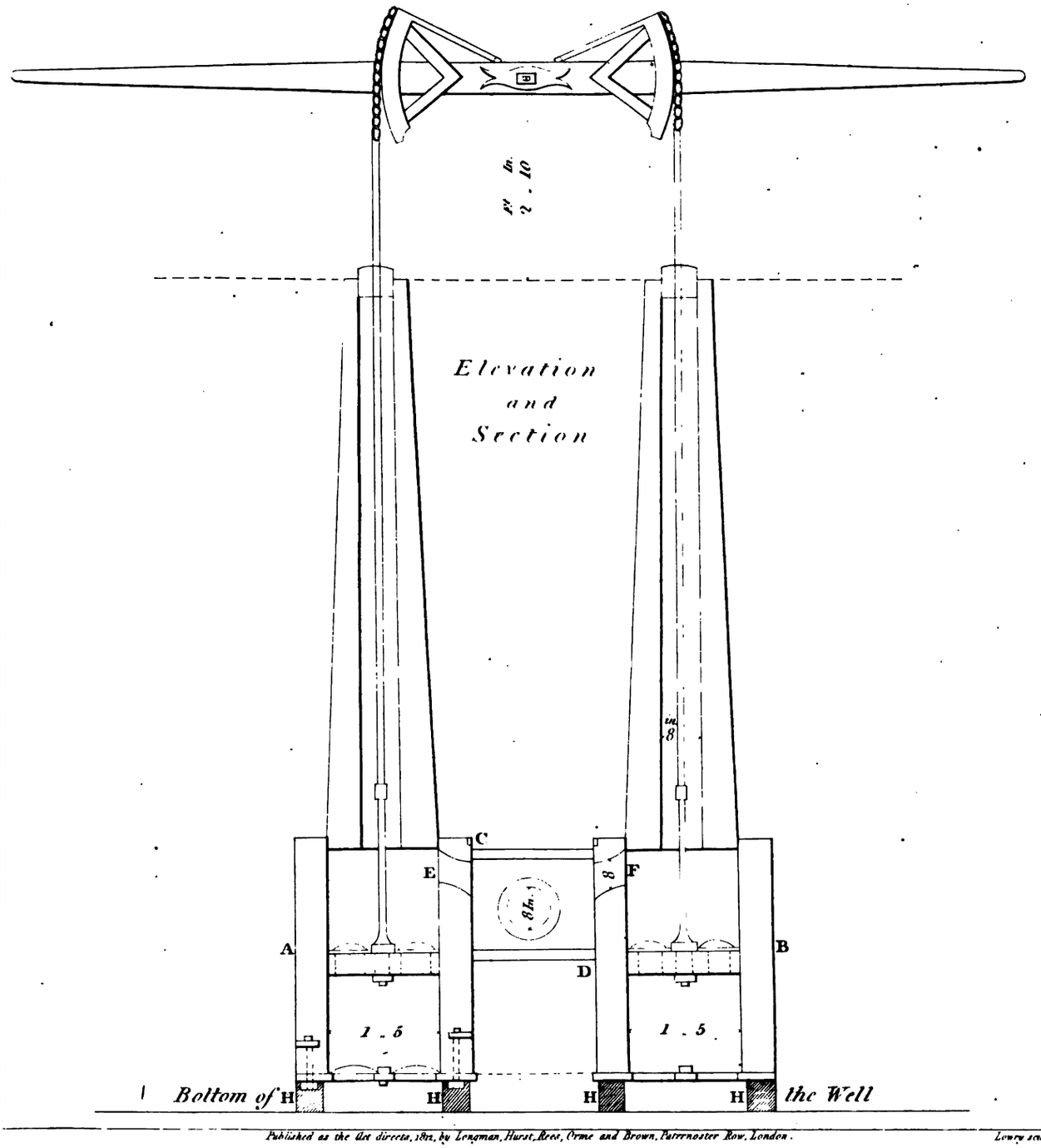
Published as the Act directs, 1812, by Longman, Hurst, Rees, Orme and Brown, Paternoster Row, London.

Lowry sculp.

PORT GLASGOW HARBOUR

Plan of the Handles.

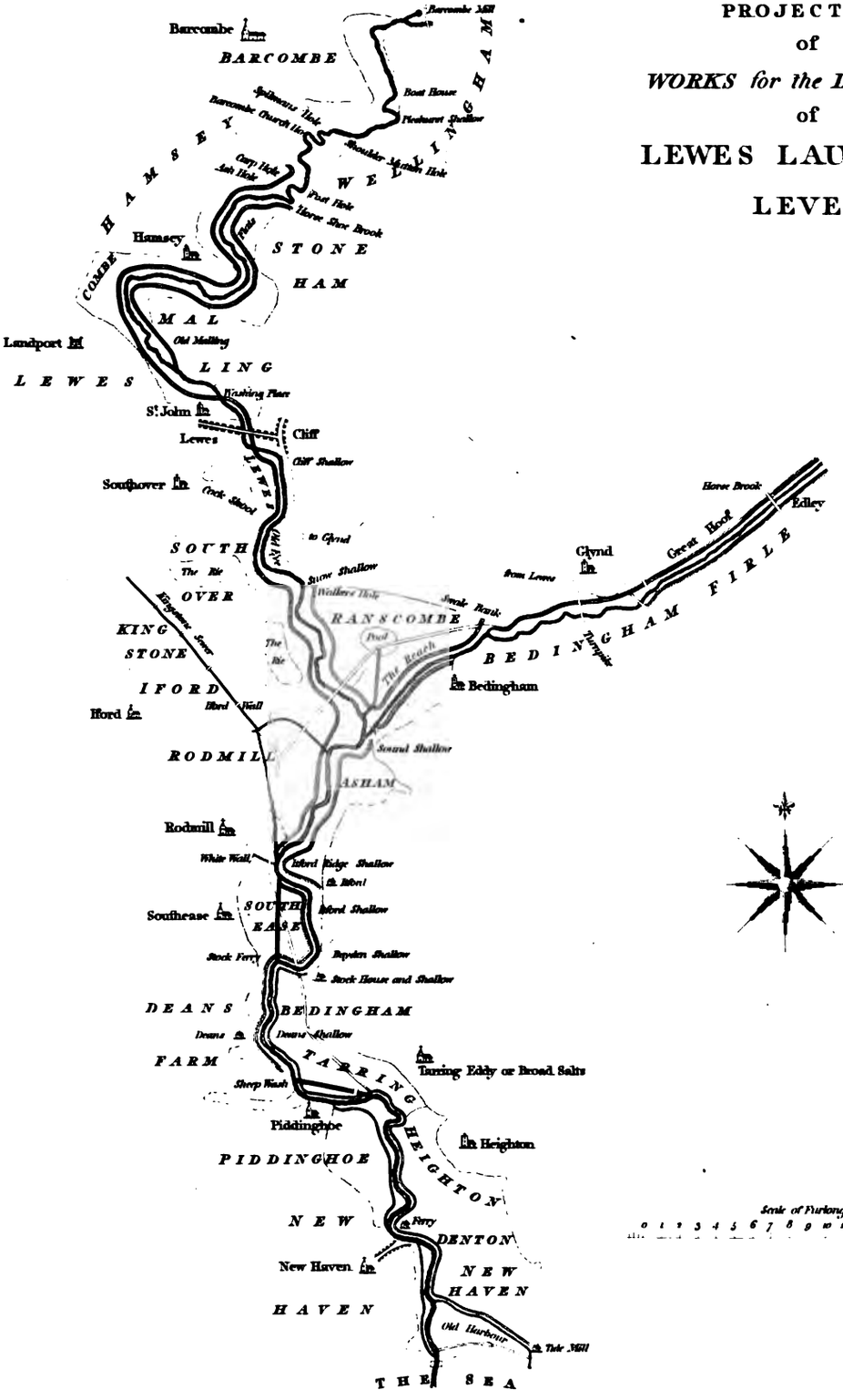




Published as the Act directs, 1812, by Longman, Hurst, Rees, Orme and Brown, Paternoster Row, London.

Lowry sculp

PROJECTION
of
WORKS for the DRAINAGE
of
LEWES LAUGHTON, LEVEL

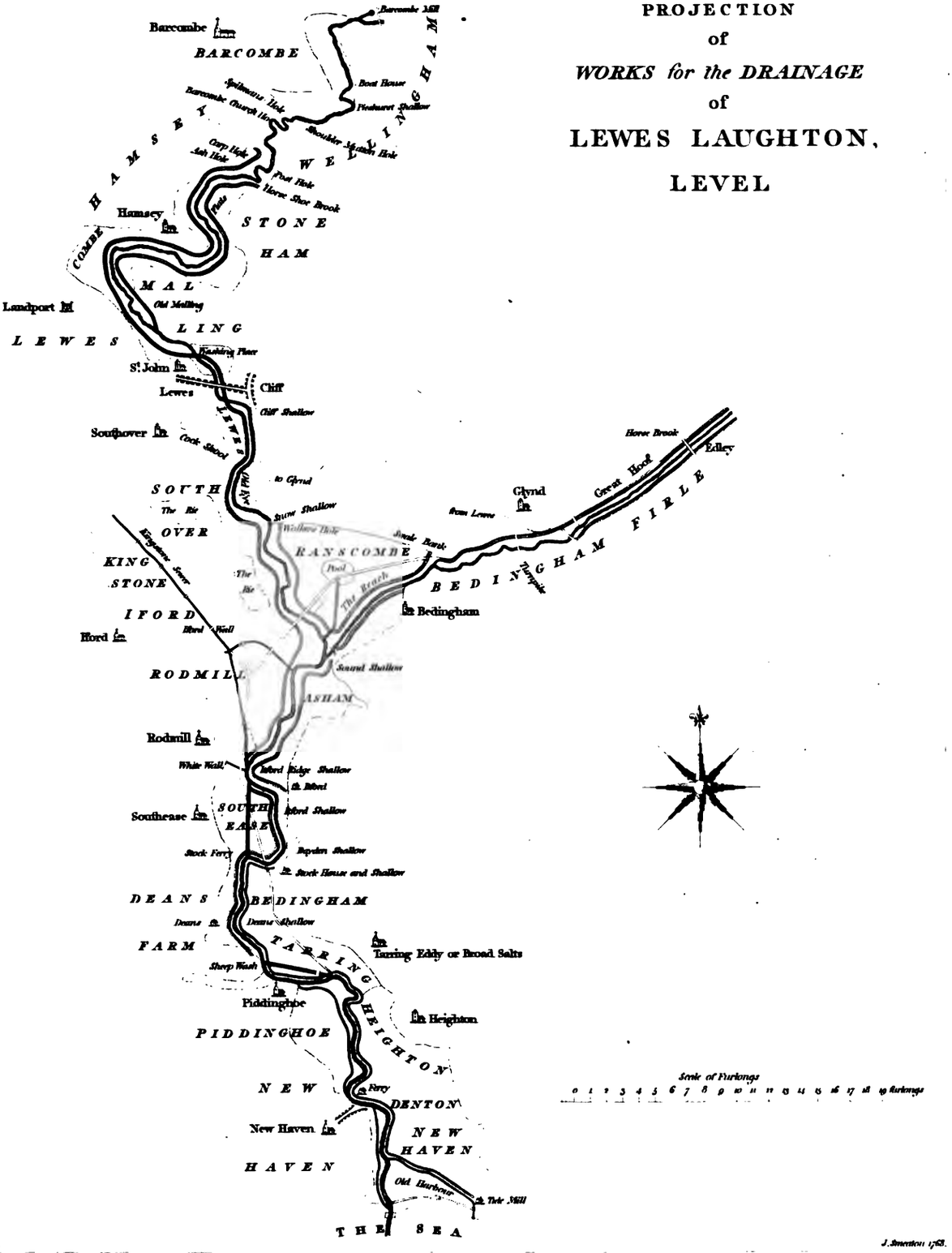


J. Farey delin.

J. Smeaton 1768.
W. Lowry sculp.

Published as the Act directs 1811, by Longman Hurst, Rees Orme and Brown, Paternoster Row, London

PROJECTION of *WORKS for the DRAINAGE* of LEWES LAUGHTON, LEVEL



J. Ferry delin.

J. Smeaton 1768.

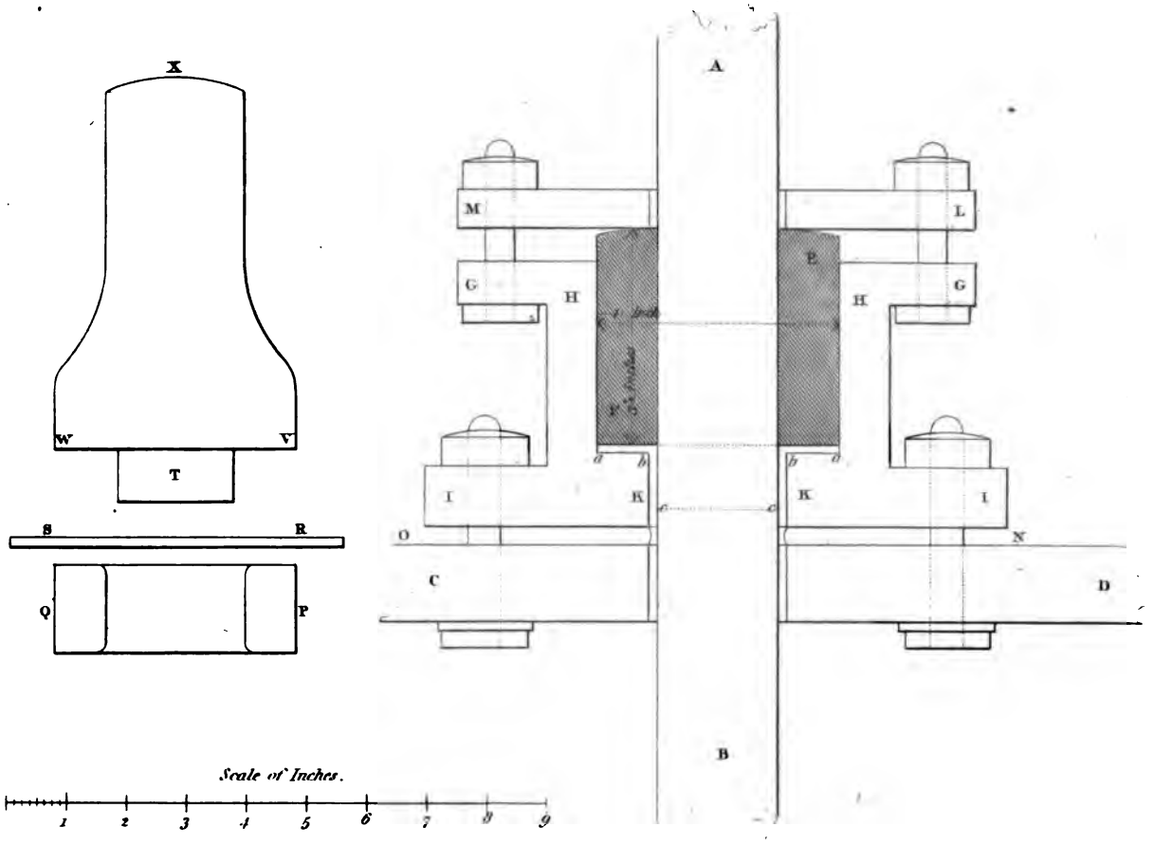
W. Lowry sculp

Published as the Act directs 1811, by Longman Hurst, Rees Orme and Brown, Paternoster Row, London

Pl. 24.

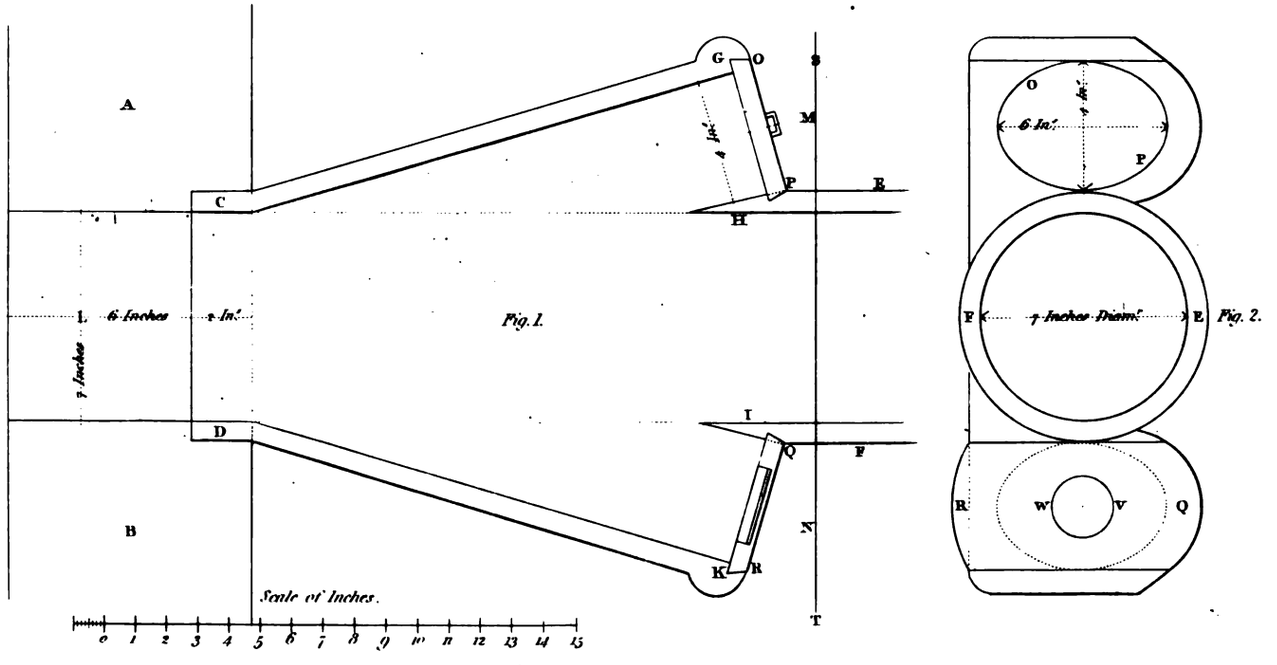
DESIGN for a COLLAR of LEATHERS, for the Blowing Engine N.º 4, at Carron.

Vol. I. p. 238.



DESIGN for a NOSE PIPE for CARRON.

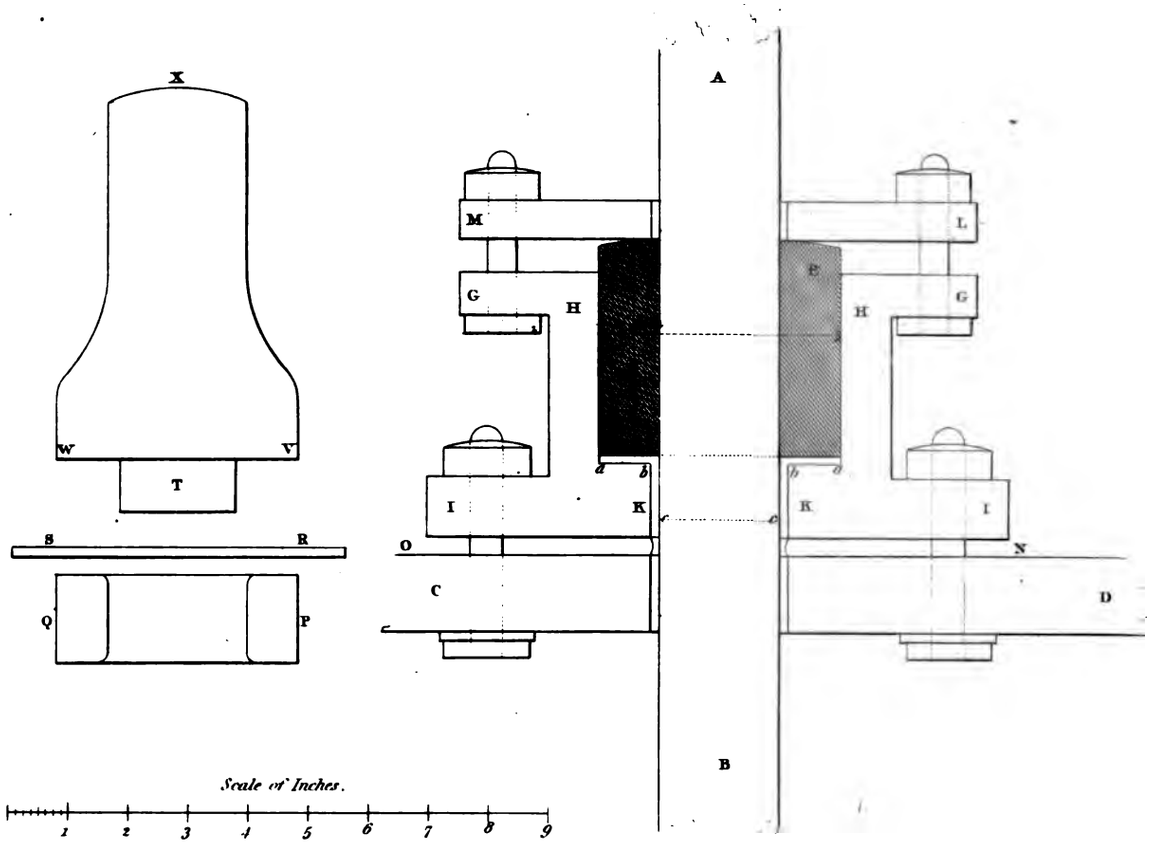
Vol. I. p. 269.



Pl. 24.

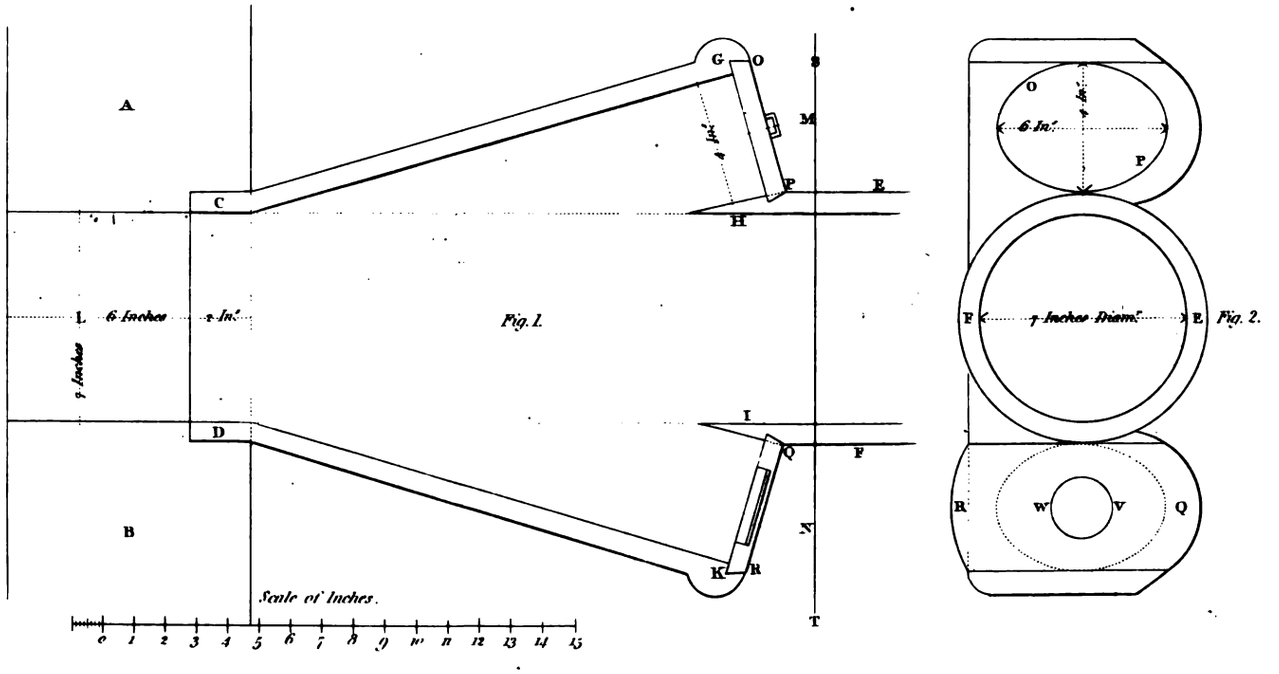
DESIGN for a COLLAR of LEATHERS, for the Blowing Engine N.º 4, at Carron.

Vol. I p. 238.

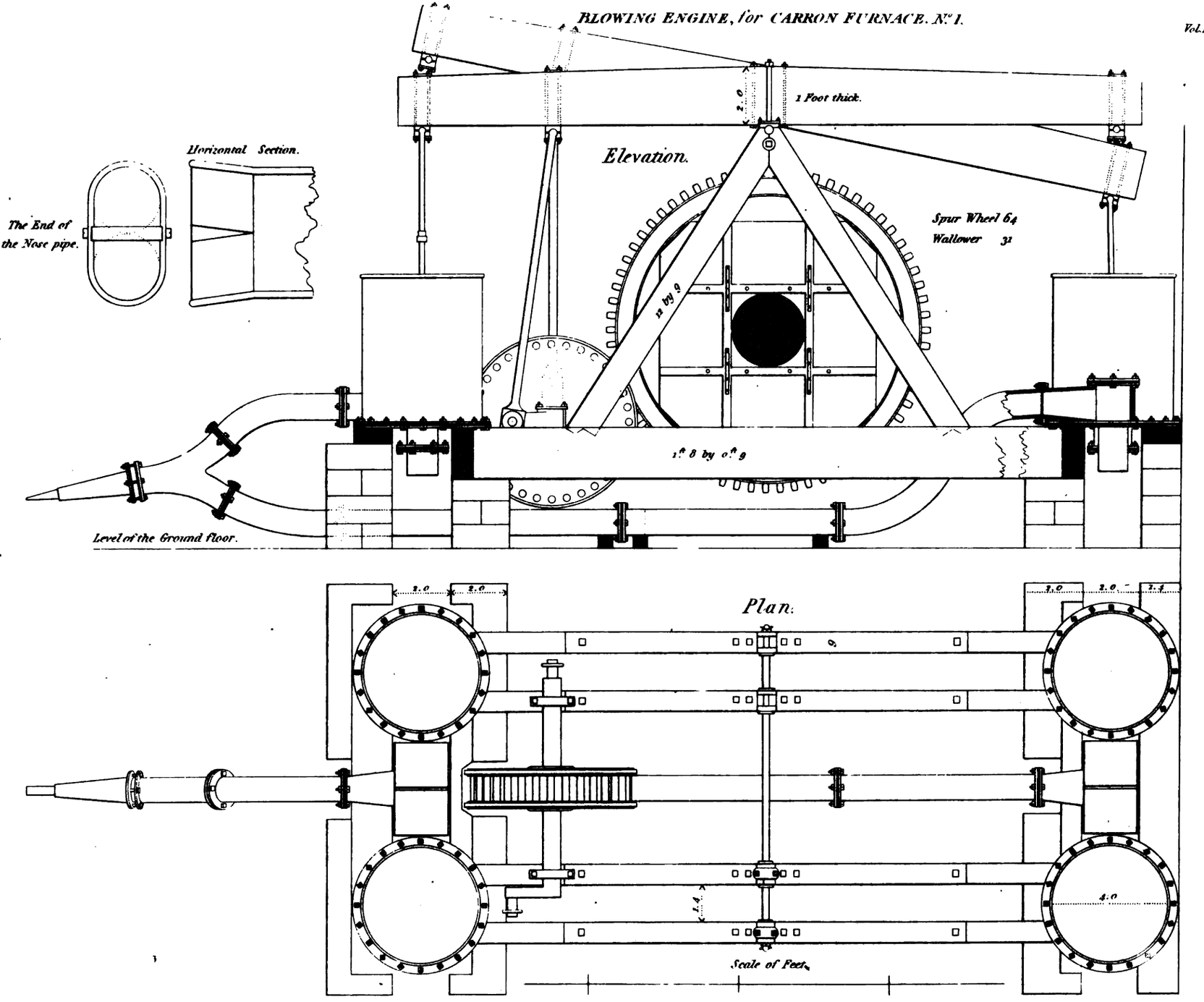


DESIGN for a NOSE PIPE for CARRON.

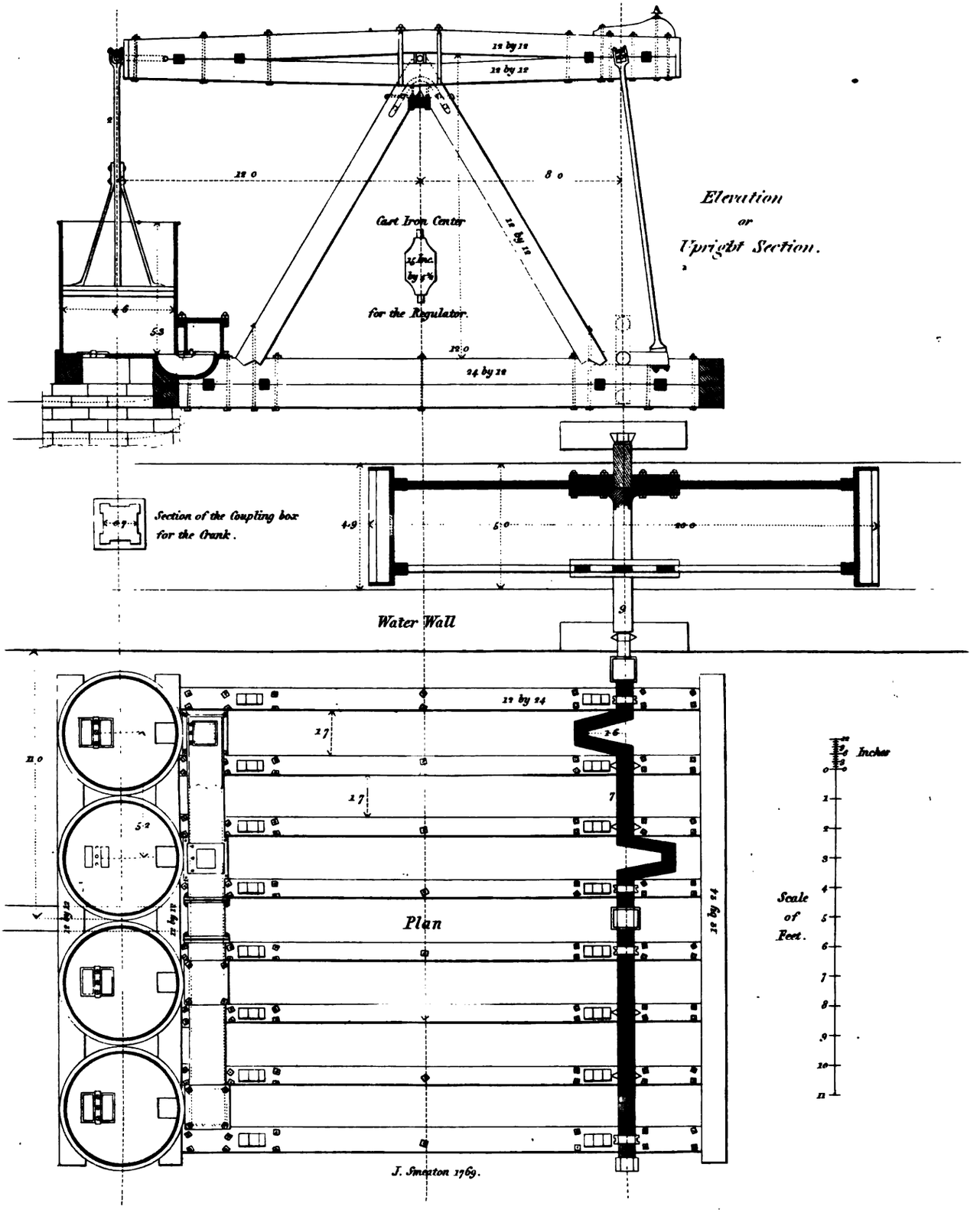
Vol. I p. 269.



BLOWING ENGINE, for CARRON FURNACE. N.° 1.



Pl. 26. *Design for the* **BLOWING MACHINE** *for the Furnace N°2. at Carron.* Vol. I. p. 2.



Reduced from Mr. Smeatons drawing by Jos. Farey.

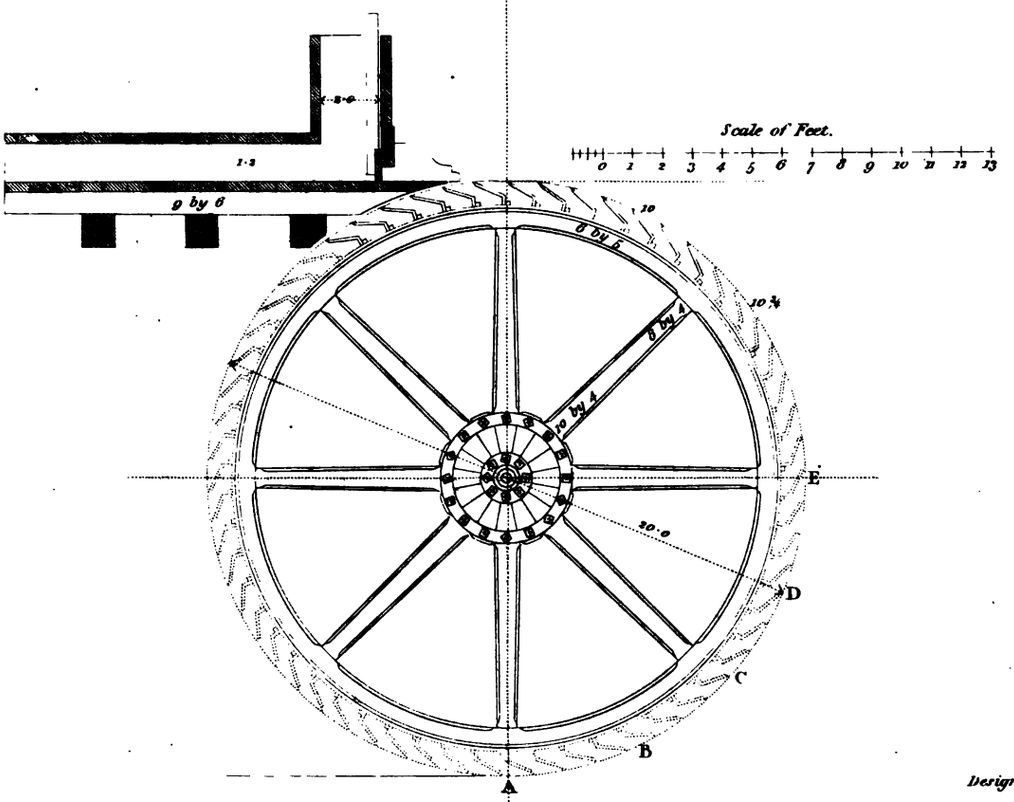
London. Published by Longman, Hurst, Rees & Orme, 1810.

Engraved by Wilson Lewis

Pl. 27.

WATER WHEEL, for the FURNACE N°II, at CARRON.

Vol.I. p. 243.

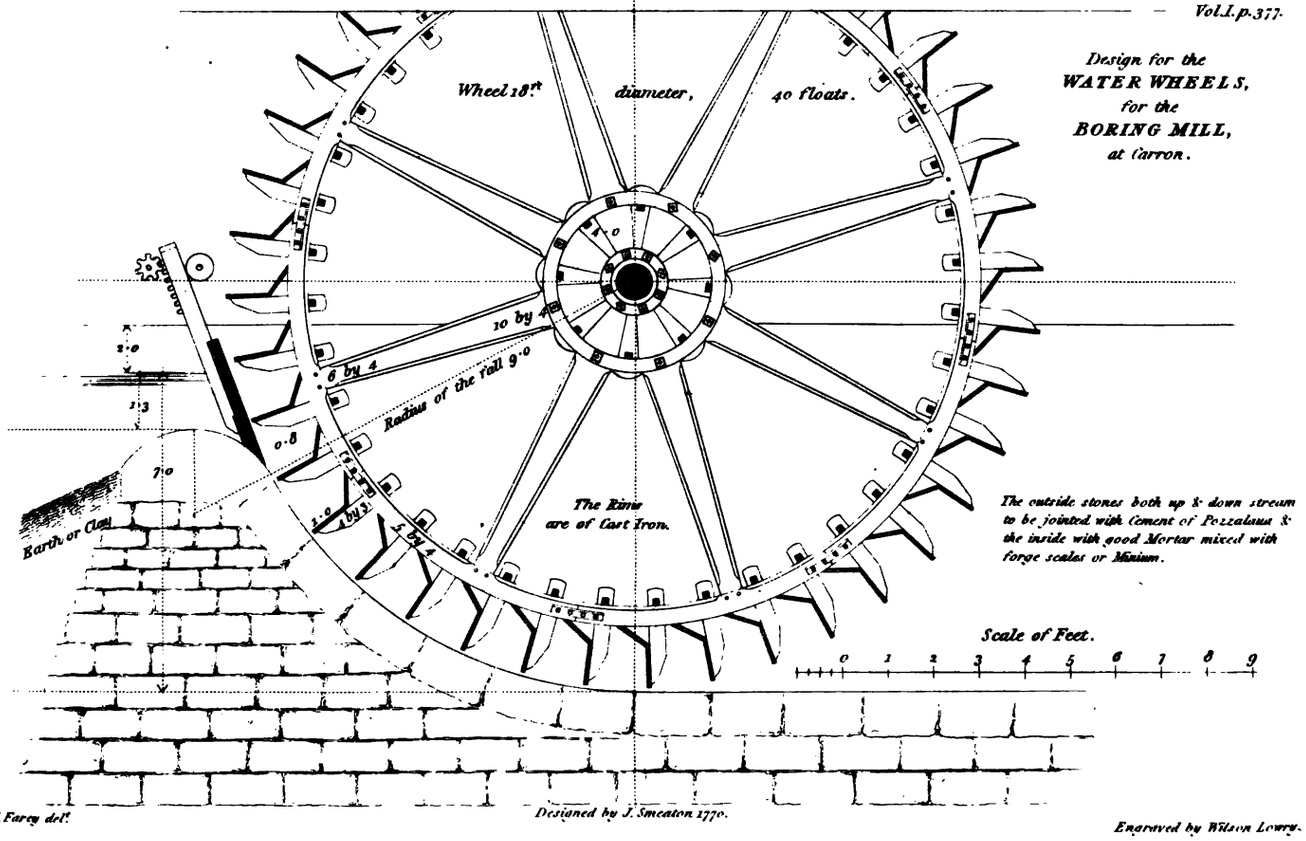


J. Farey del.

Designed by J. Smeaton, 1769.

Vol.I. p. 377.

Design for the WATER WHEELS, for the BORING MILL, at Carron.


Wheel 18 ft diameter, 40 floats.
10 by 4
6 by 4
Radius of the rail 9·0
The Rims are of Cast Iron.
Earth or Clay
Scale of Feet.
0 1 2 3 4 5 6 7 8 9

The outside stones both up & down stream to be jointed with Cement of Pozzalana & the inside with good Mortar mixed with forge scales or Minium.

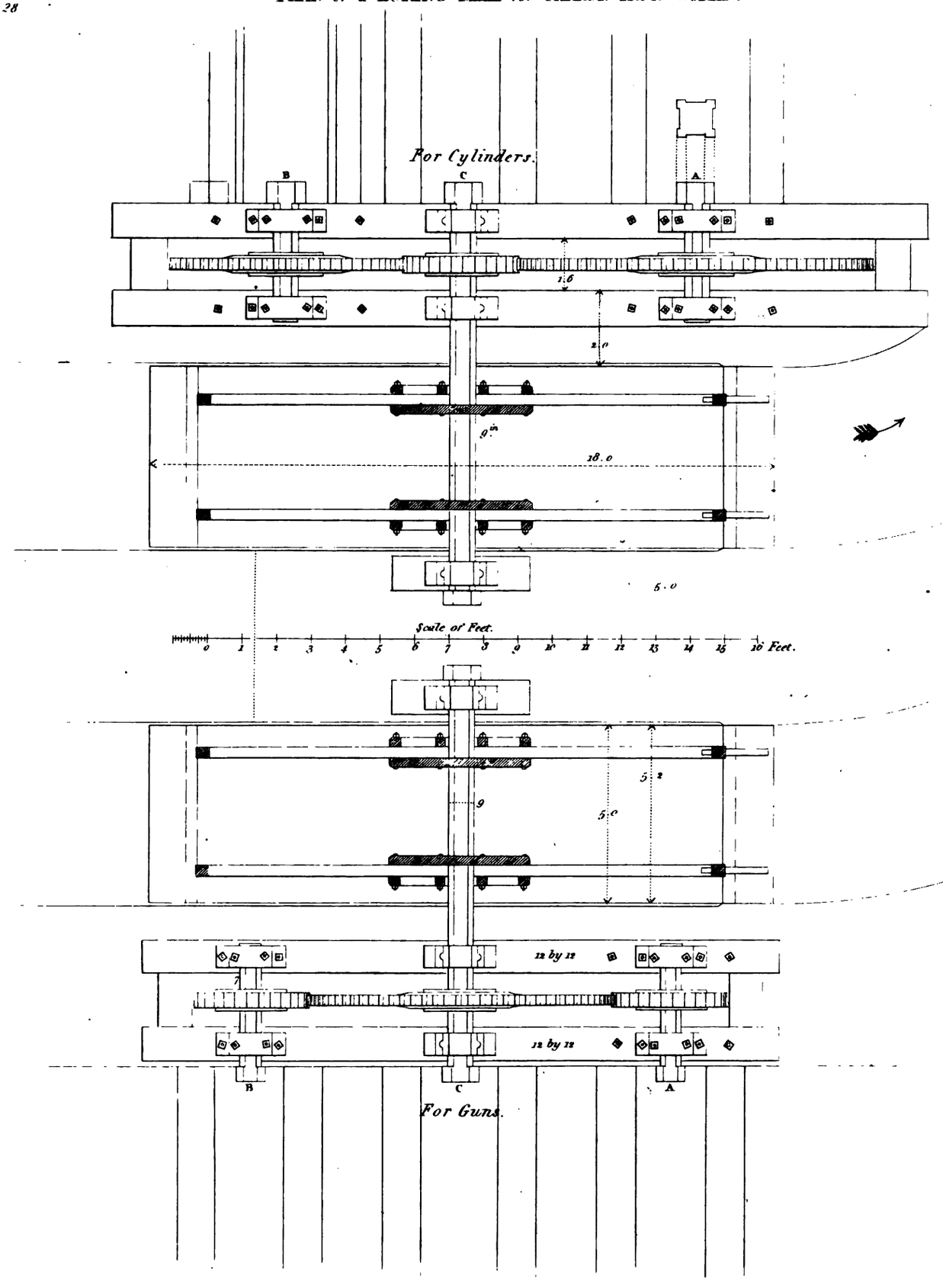
J. Farey del.

Designed by J. Smeaton 1770.

Engraved by Wilson Lowry.

Published August 1, 1810, by Longman, Hurst, Rees, & Orme, Paternoster Row, London.

PLAN of a BORING MILL for CARRON IRON WORKS.

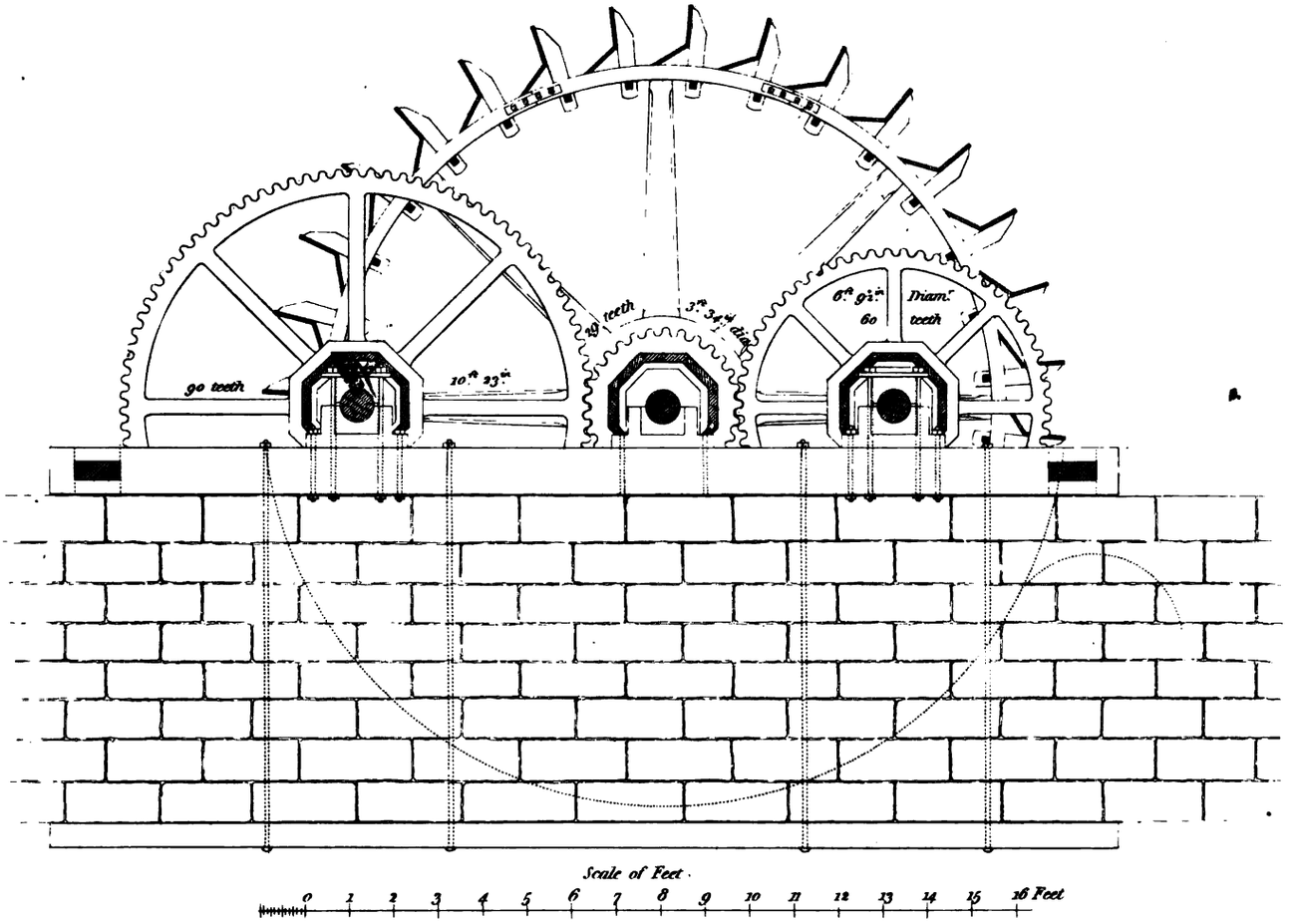


J. Farey Jun. del.

London, Published by Longman, Hurst, Rees & Orme, 1810.

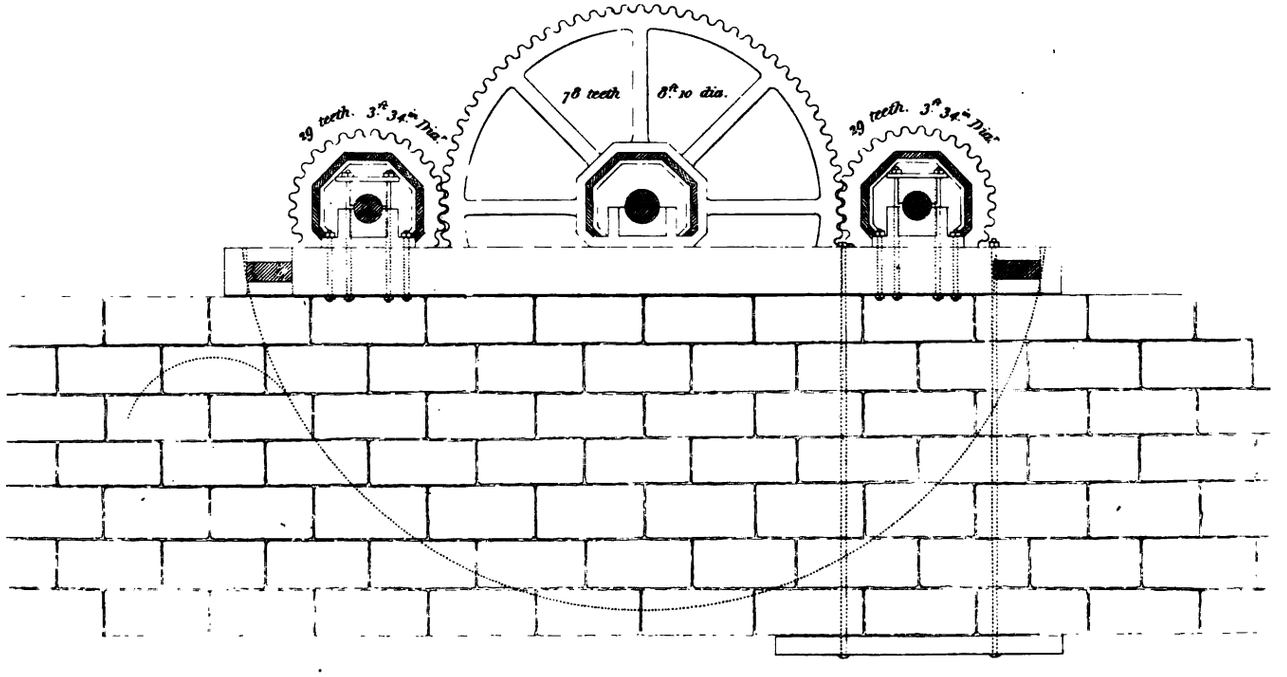
Engraved by Wilson Lowry

Upright of the BORING MILL for CYLINDERS, for Carron Works.



Scale of Feet.

Upright of the BORING MILL for GUNS.

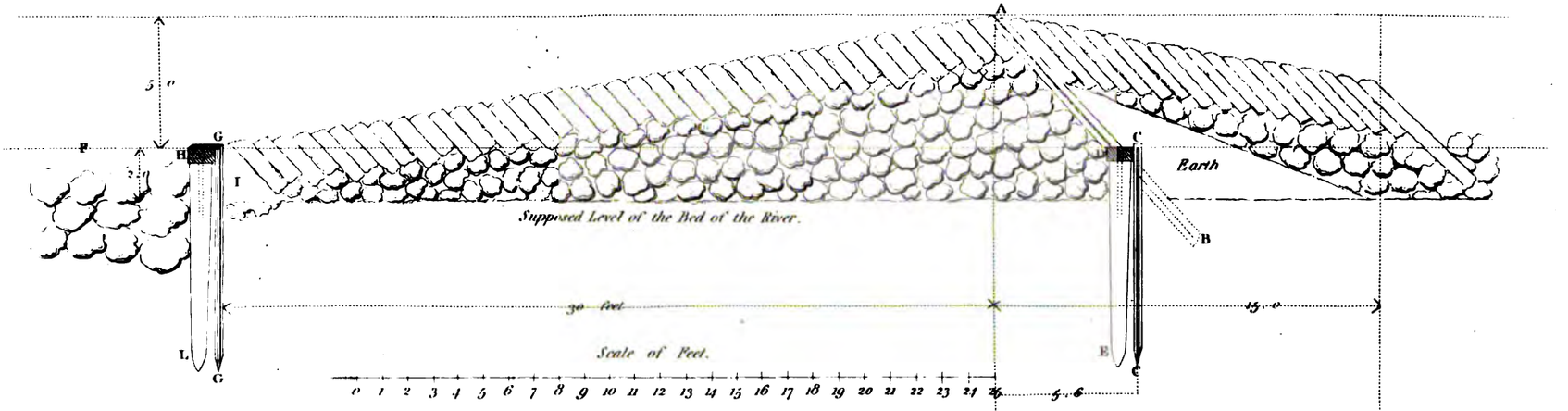


London, Published by Longman, Hurst, Rees & Orme, 1810.

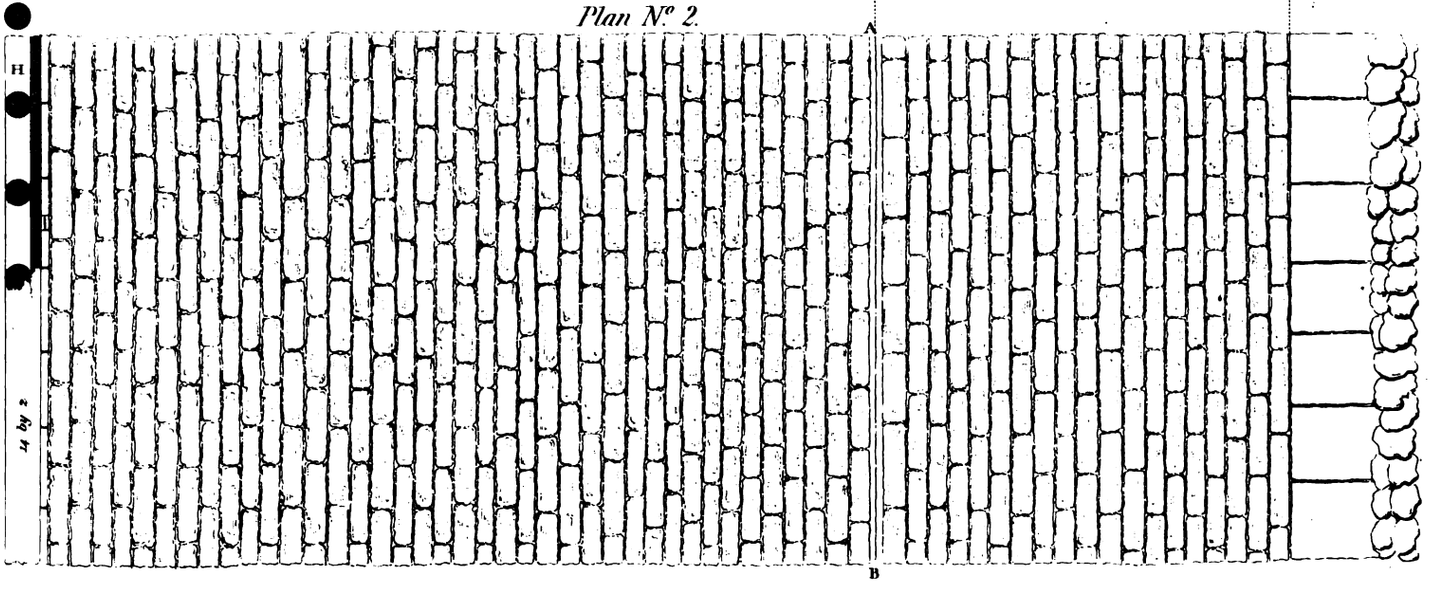
Engraved by Wilson Lowry.

Design for a DAM, upon the River Carron, at Dumi pace.

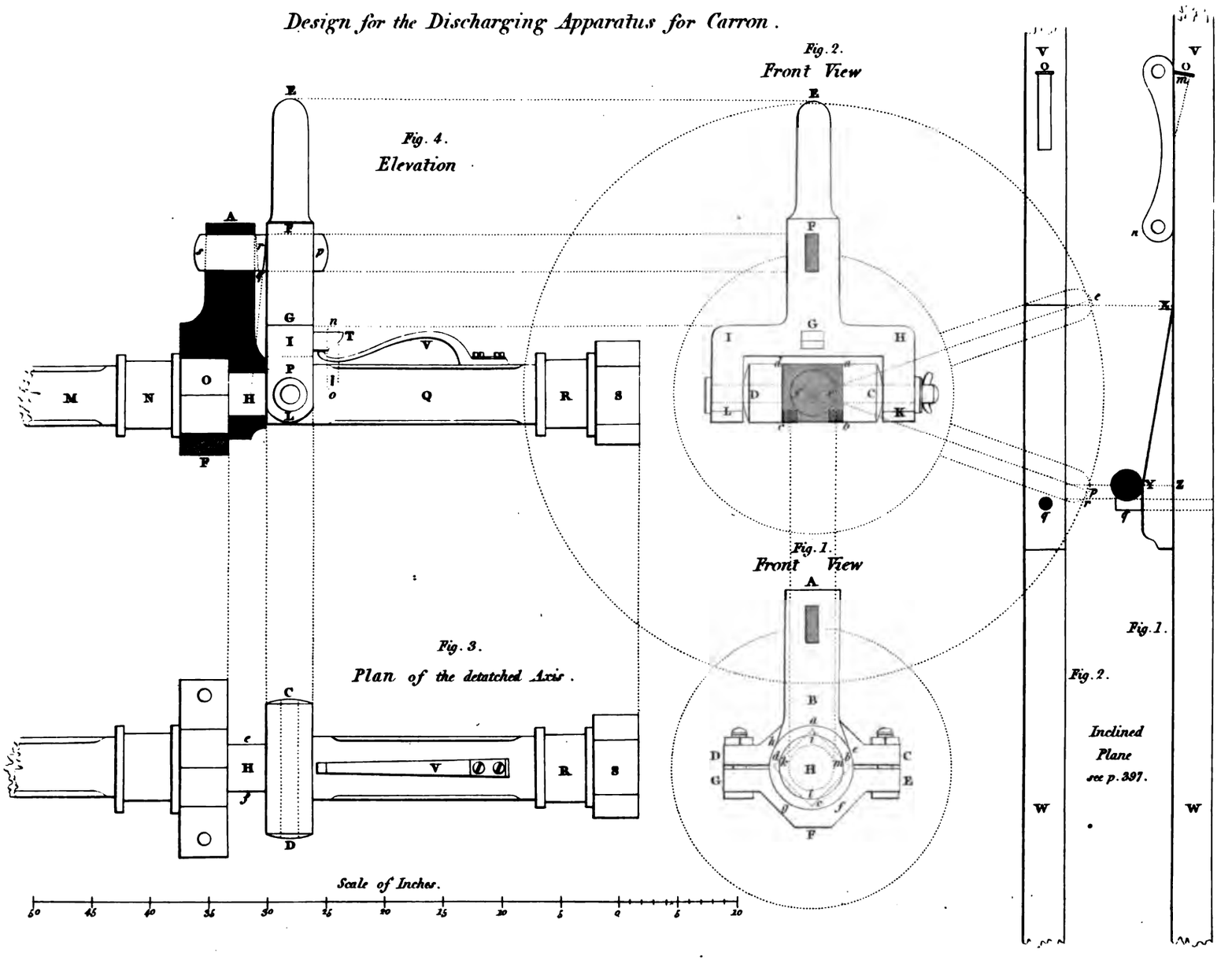
Section N.º 1.



Plan N.º 2.

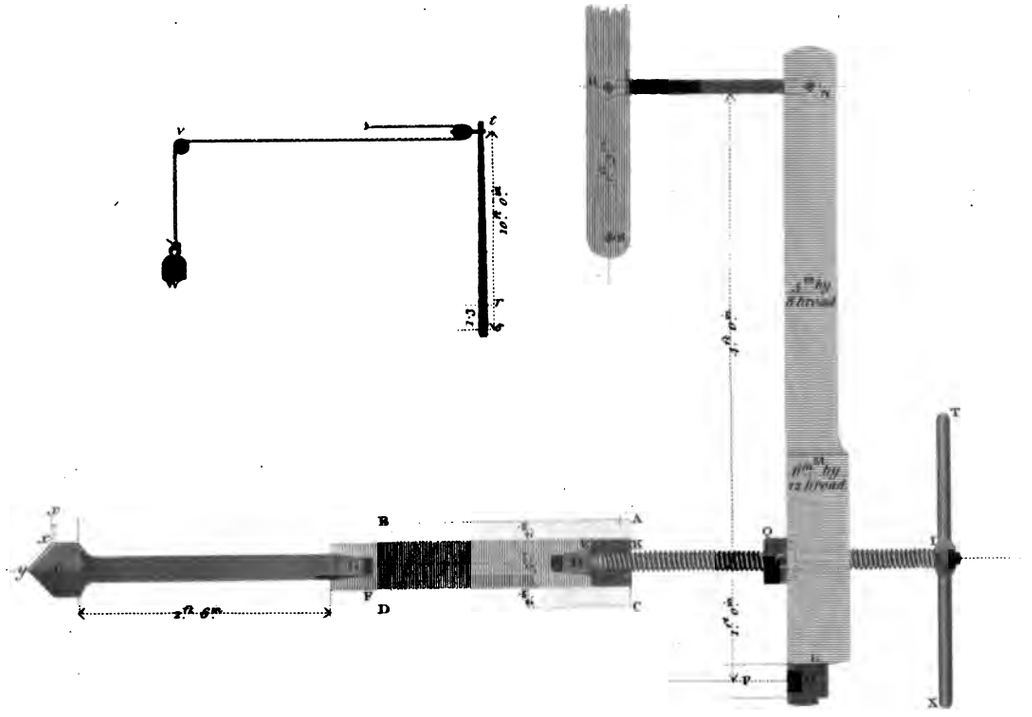


Design for the Discharging Apparatus for Carron.



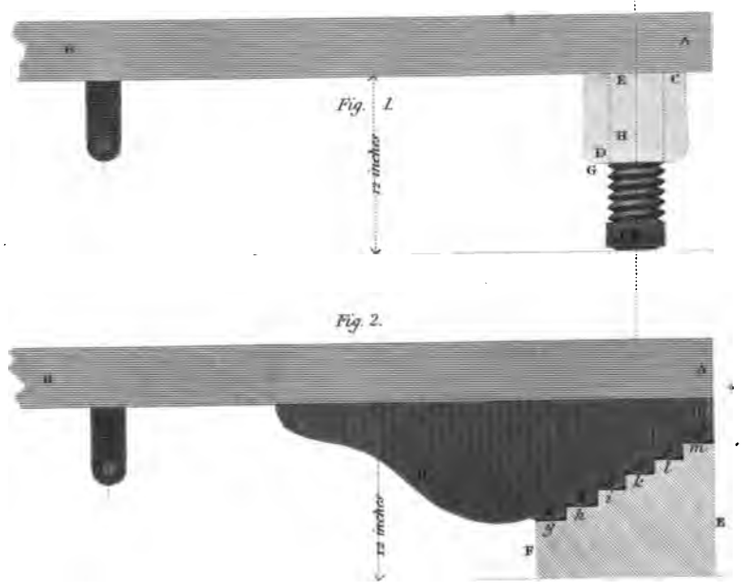
Pl. 32. Vol. I. p. 267.

Design for the APPARATUS for moving forward the BORING BARRS for the CARRONADES at CARRON, without a Carriage.



Vol. I. p. 268.

Design for Two Methods of raising the SLIDE CARRIAGES for the CARRONADES.

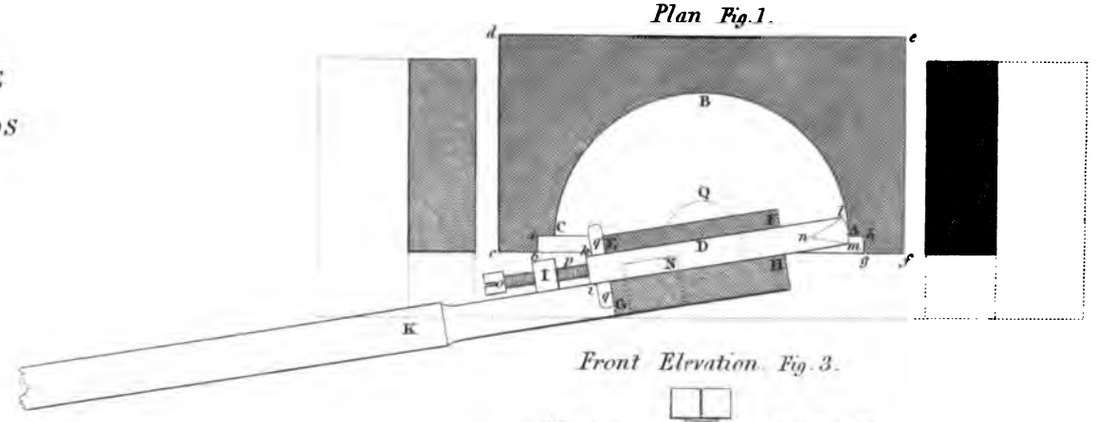


Designed by J. Smeaton 1779. Engraved by Wilson Lowry.

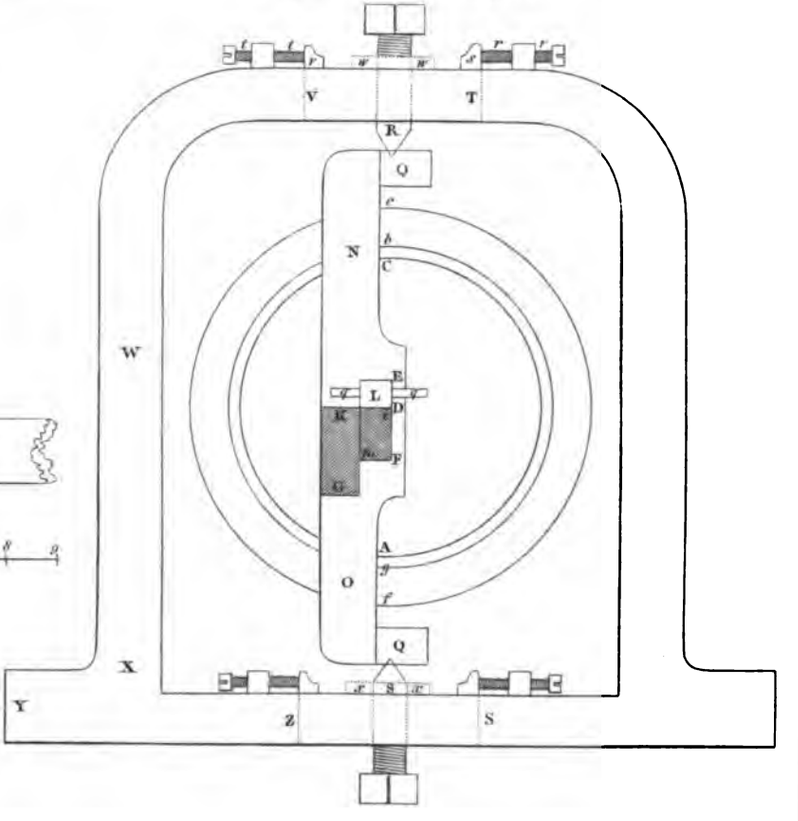
London, Published by Longman, Hurst, Rees & Orme, Paternoster Row.

DESIGN for a MACHINE for turning SHOT MOULDS by J. Smeaton 1779.

Plan Fig. 1.



Front Elevation Fig. 3.



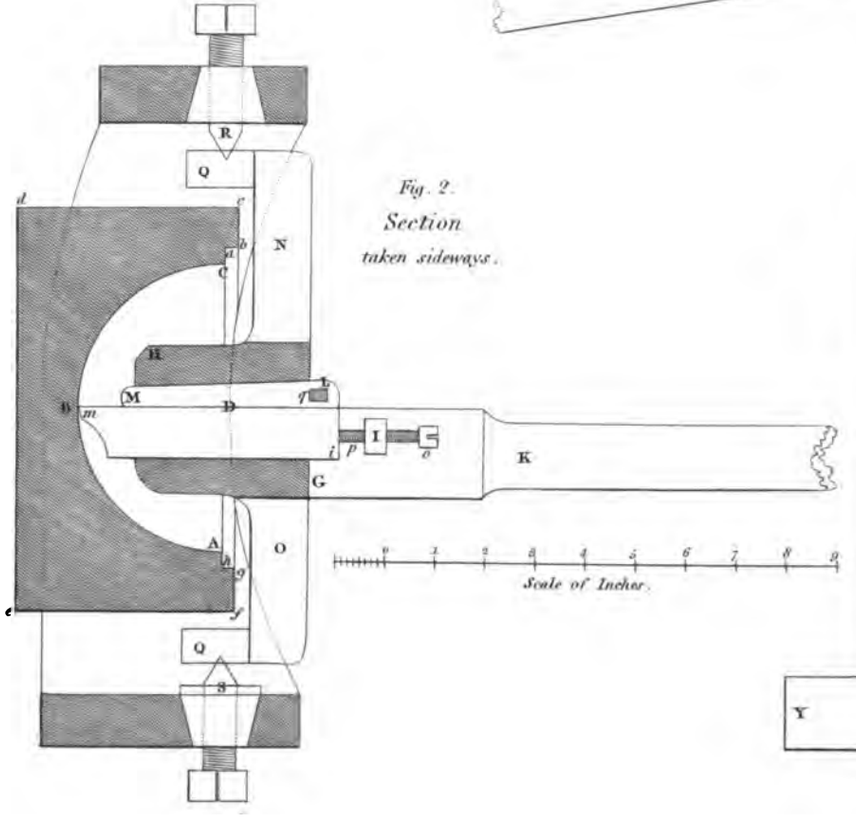


Fig. 2. Section taken sideways.

London. Published by Longman, Hurst, Rees & Orme, 1810.

SECTION OF THE WATER WAY AT LONDON BRIDGE, AS IT WAS BEFORE & AFTER THE OPENING OF THE GREAT ARCH.

Fig. 1.

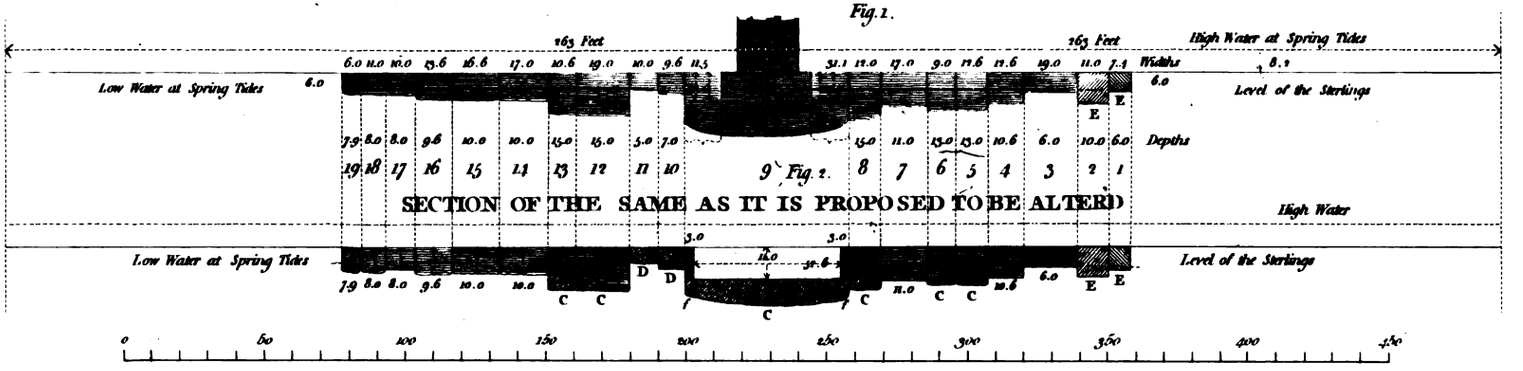
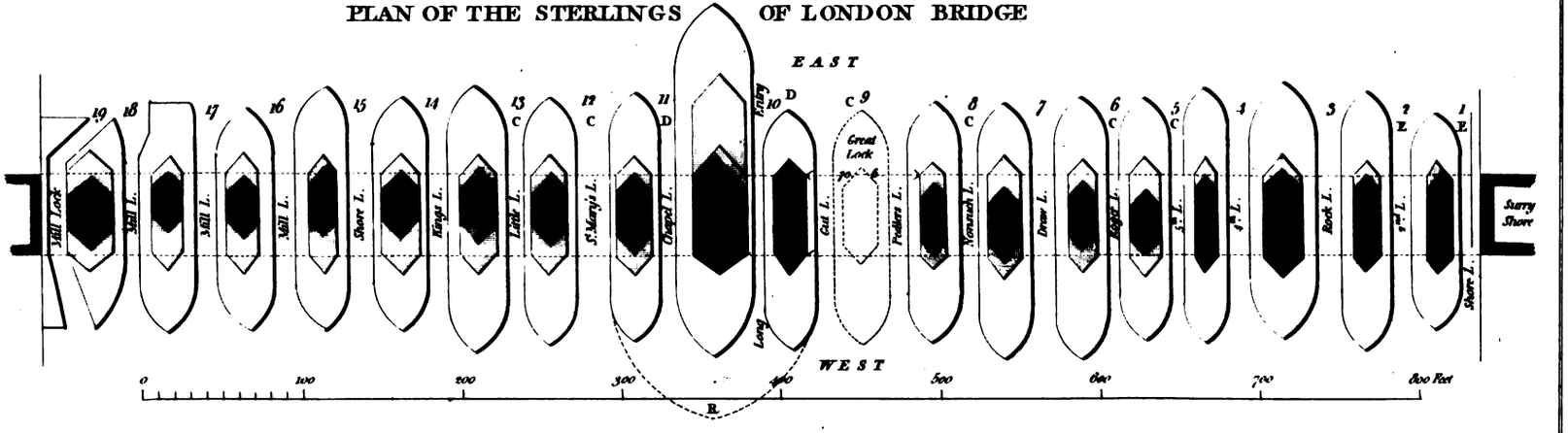
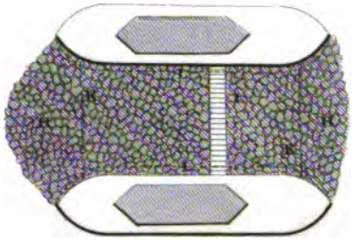

163 Feet
163 Feet
High Water at Spring Tides
Low Water at Spring Tides
Widths
Level of the Sterlings
Depths
Fig. 2.
SECTION OF THE SAME AS IT IS PROPOSED TO BE ALTERED
High Water
Low Water at Spring Tides
Level of the Sterlings
0 50 100 150 200 250 300 350 400 450

Fig. 3.

PLAN OF THE STERLINGS OF LONDON BRIDGE

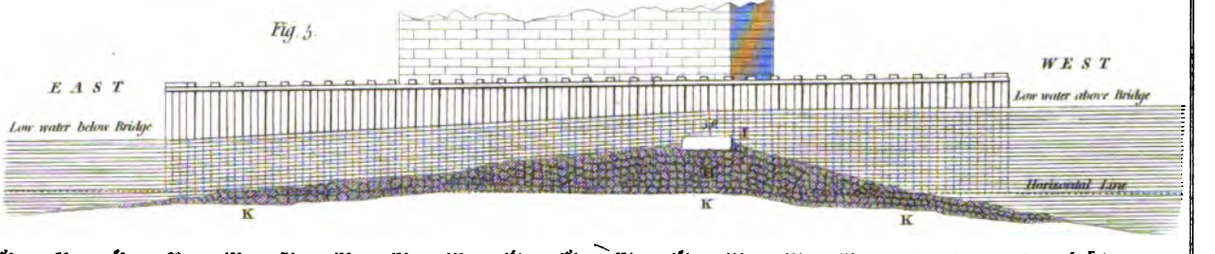


PLAN
Fig. 4.



SECTION OF THE PROPOSED WATER WAY

Fig. 5.

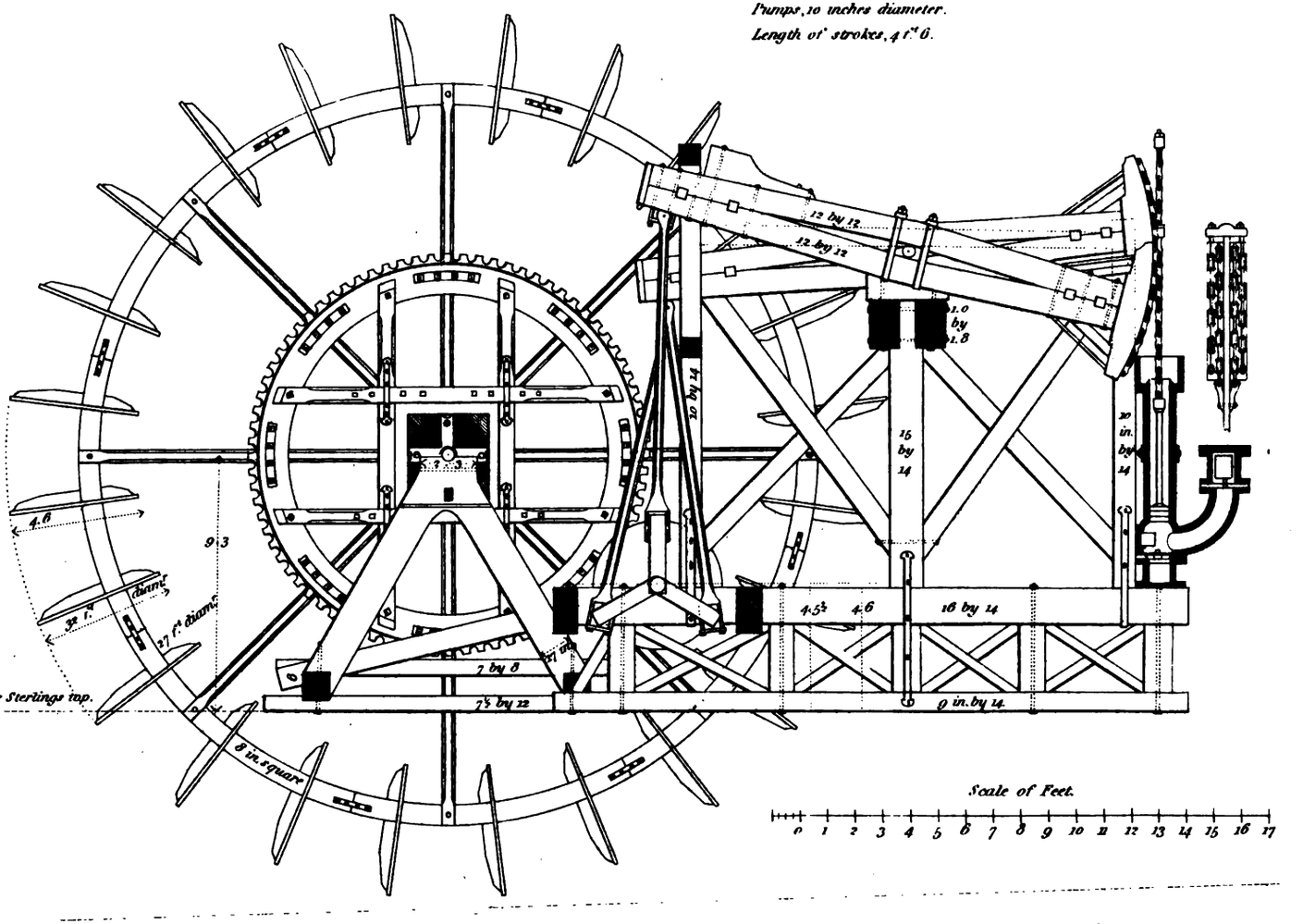


Parry delin.

Engraved by W. Lowry.

ELEVATION of the GREAT ENGINE, for the FIFTH ARCH of LONDON BRIDGE.

Spur Wheel, 80 cogs.
Lantern, ... 23 d.°
Pumps, 10 inches diameter.
Length of strokes, 4 f.t 6.



Scale of Feet.

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

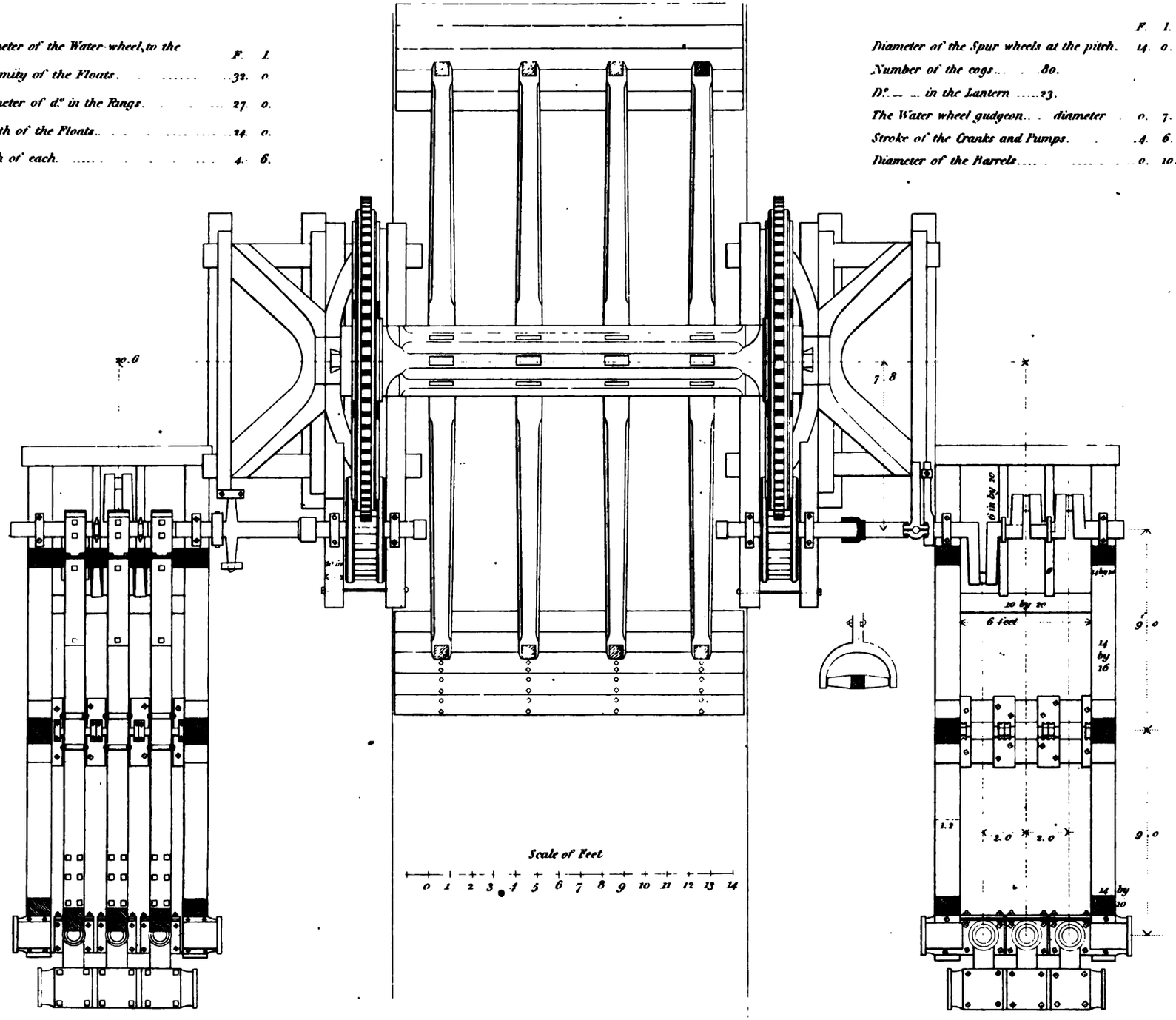
Designed by J. Smeaton, 1768.

London. Published by Longman, Hurst, Rees & Orme, 1810.

PLAN of the GREAT ENGINE, for the FIFTH ARCH of LONDON BRIDGE.

	F.	I.
Diameter of the Water-wheel, to the extremity of the Floats	32.	0.
Diameter of d.o in the Rings	27.	0.
Length of the Floats	24.	0.
Width of each	4.	6.

	F.	I.
Diameter of the Spur wheels at the pitch	14.	0.
Number of the cogs ...	80.	
D.o ... in the Lantern	23.	
The Water wheel gudgeon ... diameter	0.	7.
Stroke of the Cranks and Pumps	4.	6.
Diameter of the Barrels	0.	10.



J. Farey delin.t

Designed by J. Smeaton 1768.

Engraved by Wilson Lowry.

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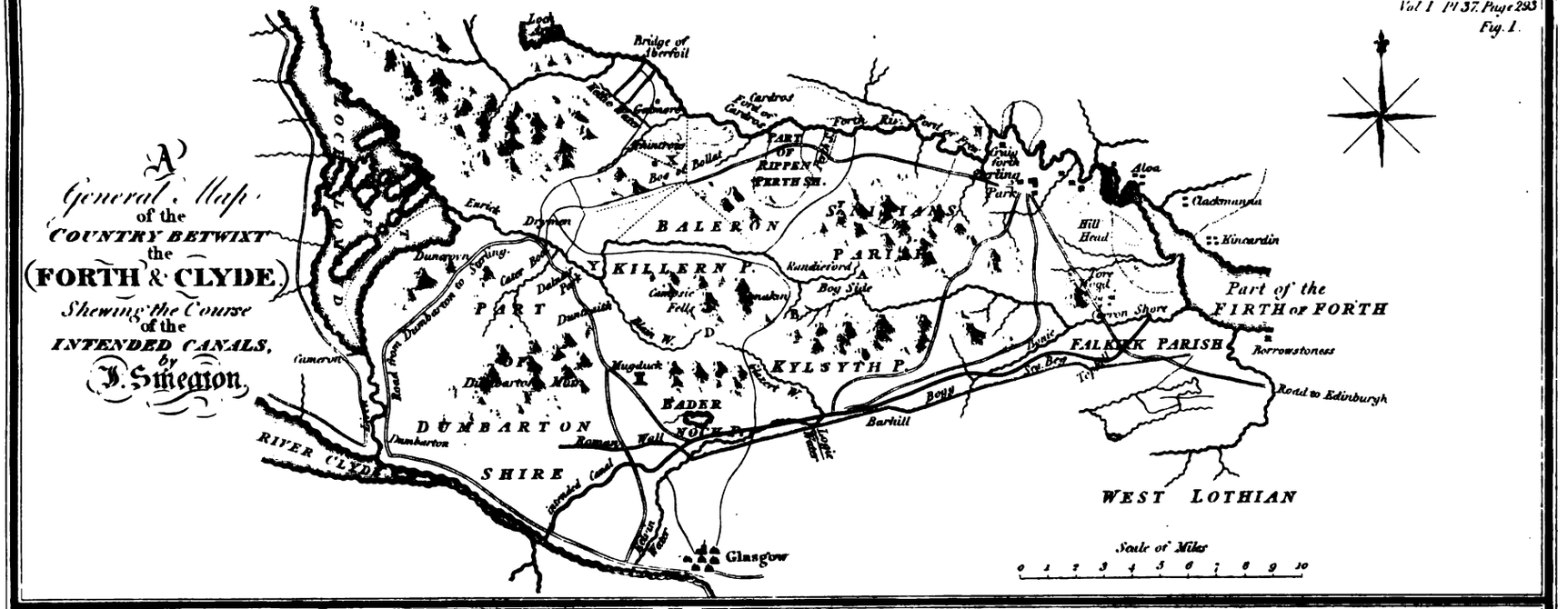
Fig. 1.

A General Map of the COUNTRY BETWIXT the (FORTH & CLYDE) Shewing the Course of the INTENDED CANALS, by J. Smeaton


Loch Lomond
Bridge of Aberfoil
Gartmore
Cardross
Forth R.
Grangemouth
Grangemouth Dock
Grangemouth Basin
Grangemouth Sluice
Grangemouth Road
Grangemouth Lock
Grangemouth Bridge
Grangemouth Ferry
Grangemouth Ferry House
Grangemouth Ferry Boat
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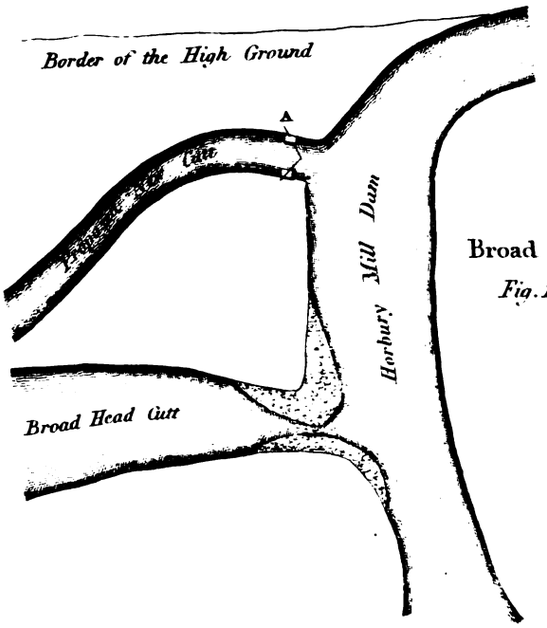
SKETCHES of the Improvements to be made on the RIVER CALDER.



Broad Cutt
Fig. 1.

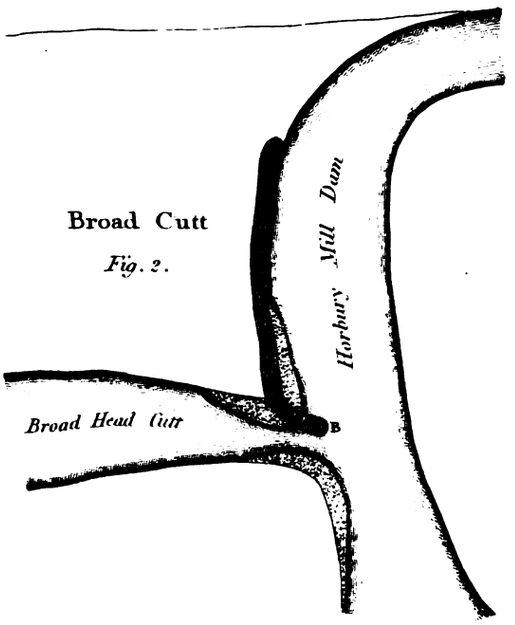
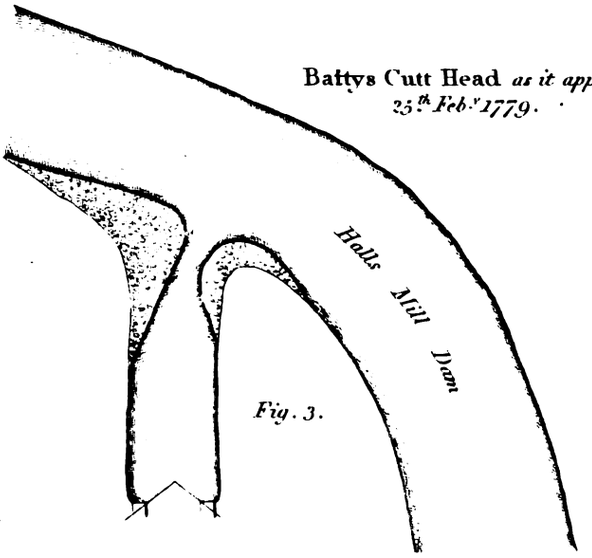
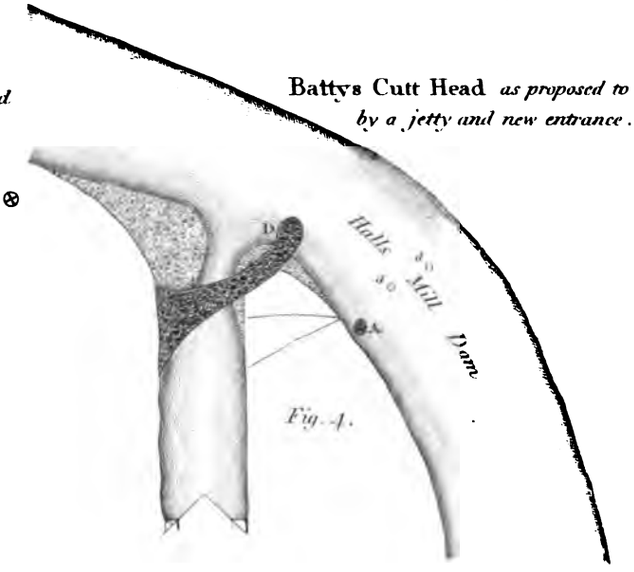


Fig. 2.



Battys Cutt Head *as it appeared 25th Febr 1779.*

Fig. 3.



Battys Cutt Head *as proposed to be alter by a jetty and new entrance.*

Fig. 4.

A PLAN of HEWICK BRIDGE and part of the RIVER URE.

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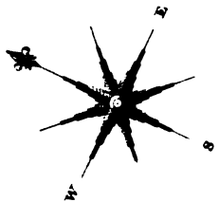
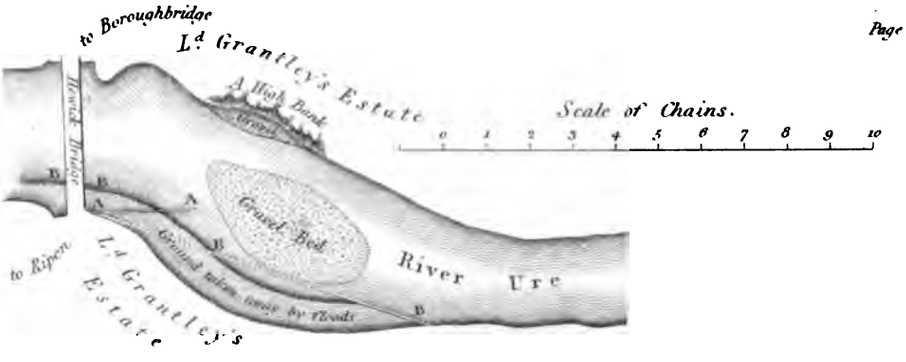


Fig. 5.



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